# The Artificial Clock-Maker.

# A TREATISE OF *Watch & Clock-work,*

WHEREIN

The Art of Calculating Numbers for most sorts of MOVEMENTS is explained, to the Capacity of the Unlearned.

Also, the History of

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Both Antient and Modern.

With other Useful Matters never before Publish'd.

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3. A nice way to correct Pendulum Watches.
4. Mr *Flamsteed*'s Equation Tables.
5. To find a *Meridian-Line*, for the Governing of Watches, and other Uses.
6. To make a *Telescope* to keep a Watch by the Fixed Stars.

By *W. D*erham M. A.

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THE

# PREFACE.

THe following Book was at first drawn up in a rude manner, only to please my self, and divert the vacant hours of a Solitary Country Life. But it is now published, purely in hopes of its doing some good in the World, among such, whose Genius and Leisure lead them to Mechanical Studies, or those whose business and livelihood it is.

Many there are, whose fault, or calamity it is, to have time lying upon their hands; and for want of innocent, do betake themselves to hurtful pleasures: This is the too common misfortune of Persons of Quality. Among some of the looser sort of which, if this Book shall find some acceptance, it may be a means to compose their loose Spirits; and by an innocent guile, initiate them in other Studies, of greater use to themselves, their Family, and Country. However, it may hinder their com-

miſſion of many ſins, which are the effects of idleneſs.

If there be any one perſon, in whom theſe good effects are produced, I ſhall think my idle hours well beſtowed, and bleſs God for it. However, upon the account of the innocence of my end in publiſhing this Book, and that it was written only as the harmleſs (I may add alſo the vertuous) ſport of leiſure hours; I think my ſelf excuſable to God and the World, for the expence of ſo much time, in a ſubject different from my Profeſſion.

But beſides, I think my ſelf under ſome little obligations of Juſtice and Charity, to publiſh the enſuing papers for the ſake of thoſe, whoſe buſineſs the Mechanick part is. I take it to be a Charity to the Trade; becauſe there are many (altho excellent in the Working part) who are utterly unskilled in the Artificial part of it. And then it is a debt I pay: becauſe I owe ſomewhat of health, as well as diverſion to the Study, and Practice of this ſort of Mechanicks. And the beſt requital I can make for my treſpaſs, is to publiſh what I have had better opportunities perhaps of Learning than many Workmen have.

And further yet, there is another reaſon, which much prevailed with

me

me to publiſh this Book, *viz.* Becauſe no body, that I know of, hath prevented me, by treating ſo plainly and intelligibly of this ſubject, as to be underſtood by a Vulgar Workman. I have often wondered at it, that ſo uſeful and delightful a part of Mechanical Mathemeticks ſhould lie in any obſcurity, in an age wherein ſuch vaſt improvements have been made therein, and when many Books are daily publiſhed upon every ſubject. I ſpeak here of this Art remaining in obſcurity; not as if nothing was ever written of it, and I the Inventer of AutomaticalComputation.

But altho I cannot aſſume the glory of being the firſt Writer upon this ſubject, yet very few have as yet done it; of which I ſhall next give ſome account.

*Cardan*, *Kircher*, and *Scottus* promiſed it; but I do not find they ever publiſhed any thing to the purpoſe of it. Our great Mr *Oughtred* I take to be the firſt that ever wrought to any purpoſe about the Calculation of *Automata*: And I believe he was the firſt that brought that Art under Rules, in his little treatiſe called *Automata*. Which Book was firſt ſurreptitiouſly publiſhed in *Engliſh* in a little Book called *Horolog. Dialogues*, in the year 1675; and afterwards far

more compleatly in *Latin*, at the Theatre in *Oxon*, among Mr *Oughtred's Opusc. Mathem.* in the year 1677. This last edition it was my misfortune not to meet with, until it was too late, and therefore I have been forced to quote the first and worst in my Book.

What Mr *Oughtred* had wrapt up in his Algebraick obscure Characters was afterwards put into plainer Language by that excellent Mathematician Sir *Jon. Moor*, with some additions of his own; which you have in this *Math. Compend.* and since him, by Mr. *Leyborn*, in his *Pleasure with Profit*.

I hope I shall not be judged to have transgressed the Rules of Modesty, in coming after three such famous men; neither should I venture that censure, but for two reasons. One is, I find by experience, that what they have written, is understood by very few Workmen, and therefore I have endeavoured, with all industry, to make the matter as plain as I could for such. For which reason, I hope the more learned Reader will excuse my using many words, when fewer would have served his turn; and that I have condescended to low things, (and to him needless) as teaching the Golden-rule, *&c.* The other reason is, that what those three have written, relates only,

or

or chiefly to the Watch-part. To which I have added ſeveral other things of my own: particularly the Calculation of the Clock-part, *&c.* I have been forced to reduce to Rules my ſelf. And to name no more, the Hiſtorical part hath not been ſo much as attempted before, that I know of.

Theſe Reaſons will, I hope, excuſe me with the moſt cenſorious Reader, not only for preſuming to write after ſo accurate a piece, as Mr. *Oughtred*'s is; but alſo the Novelty of the ſubject, will I hope procure for me a candid interpretation of the faults and blunders, that I may have unwittingly committed.

To the preceding account of what others have written (which ſhews what help I have had from printed Books) I ſhall ſubjoyn my acknowledgments, and thanks to the principal of my friends, who have given me their aſſiſtance in compiling this Book. But their names I ſhall not make more publick than mine own, being unwilling to be diſcovered my ſelf. In the Chap. of the Terms of Art, I owe much to the aſſiſtance of Mr. *L. Br*.... a judicious Workman in *Fanchurch-ſtreet*, who drew me up a Scheme of the Clock-maker's Language. In the Hiſtory of the Modern Inventions, I have had (among

ſome others) the aſſiſtance of the ingenious *Dr. H....* and *Mr. T...*: The former being the Author of ſome, and well acquainted with others, of the Mechanical Inventions of that fertile Reign of King *Charles* the II. and the latter actually concerned in all, or moſt of the late inventions in Clock-work, by means of his famed skill in that, and other Mechanick operations.

There are ſome other contrivances of this laſt age (beſides thoſe I have mentioned) which I have paſſed over in ſilence; becauſe either they are only branches, or improvements of the inventions I have taken notice of; (ſuch as ſeveral ways of repeating work, *&c.*) or elſe, they only collaterally relate to Watch-work (as the inventions of Cutting-Engines, Fuſy-Engines, *&c.*) To treat of all theſe, would ſwell my Book far beyond its intended bounds; which I have already ſomewhat exceeded I ſhall therefore commit this task to ſome better Pen, hoping that no perſon will take it amiſs, that I have not mentioned his inventions which I have been beholden to him for the relation of.

For the reaſons laſt mentioned, I have alſo left out of my Book, a Chapter of the Art of making, and uſing many ſorts of Sodders, the way of colouring Metals,

Metals, *&c.* uſeful in the practice of Clock-work. This I had prepared for the ſake of Mercurial Gentlemen, but omitted printing it, and ſome other things, out of Charity to poor Apprentices and other Workmen, whoſe purſes I am unwilling my volume ſhould too much exceed.

If I have at any time invaded the Workman's province, it was not becauſe I pretend to teach him his Trade; but either for Gentlemen's ſakes, or when the matter led me neceſſarily to it.

I have nothing more to add, but that I would have this little Treatiſe looked upon only as an eſſay, which I hope will prompt ſome abler pen to perform the task better, eſpecially in the Hiſtorical part. For ſince Watch-work oweth ſo much to our Age, and Country, 'tis pity that it ſhould not be remembred: eſpecially when we cannot but lament the great defect of Hiſtory, about the beginning and improvements of this ingenious and uſeful Art.

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The

# The Artificial CLOCK-MAKER.

## CHAP. I.

### *Of the Terms of Art, or Names by which the parts of an* Automaton *are called.*

IT is neceſſary that I ſhould ſhew the meaning of the Terms which Clock-makers uſe, that Gentlemen and others, unskilful in the Art, may know how to expreſs themſelves properly, in ſpeaking; and alſo underſtand what I ſhall ſay in the following Book.

I ſhall not trouble the Reader with a recital of every name that doth occur, but only ſuch as I ſhall have occaſion to uſe in the following diſcourſe, and ſome few others that offer themſelves,

upon a transient view of a piece of work.

I begin with the more general Terms: as, the *Frame*; which is that which contains the Wheels, and the rest of the work. The *Pillars* and *Plates*, are what it chiefly consists of.

Next for the *Spring*, and its appurtenances. That which the Spring lies in, is the *Spring-box*: that which the Spring laps about, in the middle of the Spring-box, is the *Spring-Arbor*; to which the Spring is hooked at one end. At the top of the Spring-Arbor, is the *Endless-Screw*, and its Wheel.

That which the Spring draweth, and about which the Chain or String is wrapped, and which is commonly taper, is the *Fusy*. In larger work, going with weights, where it is cylindrical, it is called the *Barrel*: The small Teeth at the Bottom of the Fusy, or Barrel, that stop it in winding up, is the *Ratchet*. That which stops it when wound up, and is for that end driven up by the String, is the *Garde-caut*, or *Guard-Cock*, as others; and *Gard-du-Cord*, and *Gard-du-Gut*, as others call it.

The parts of a *Wheel* are, the *Hoop*, or *Rim*: the *Teeth*: the *Cross*: and the *Collet*, or piece of Brass, soddered on the Arbor, or Spindle, on which the Wheel is rivetted.

A *Pinion* is that little Wheel, which plays in the Teeth of the Wheel. Its teeth (which are commonly 4, 5, 6, 8, *&c.*) are called *Leves*, not Teeth.

The ends of the Spindle are called *Pevetts*: the holes in which they run *Pevet-holes*.

The guttered Wheel, with Iron ſpikes at the bottom, in which the line of ordinary Houſe-Clocks doth run, is called the *Pully*.

I need not ſpeak of the *Dial-Plate*, the *Hand*, *Screws*, *Wedges*, *Stops*, *&c.*

Thus much for general Names, which are common to all parts of a Movement.

The parts of a *Movement*, which I ſhall conſider, are the *Watch*, and *Clock*.

The *Watch part* of a Movement is that which ſerveth to the meaſuring the hours. In which the firſt thing I ſhall conſider is the *Ballance*: whoſe parts are, the *Rim*, which is the circular part of it: the *Verge*, is its Spindle: to which belong the two *Pallets*, or *Nuts* which play in the fangs of the Crown-Wheel: in Pocket Watches, that ſtrong ſtud in which the lower Pevet of the Verge plays, and in the middle of which one Pevet of the Crown-Wheel runs, is called the *Pottans*, or rather *Potence*: the wrought

piece which covers the Ballance, and in which the upper Pevet of the Ballance plays, is the *Cock*. The ſmall Spring in the new Pocket Watches is the *Regulator*.

The parts of a *Pendulum* are, the *Verge*, *Pallets* and *Cocks*, as before. The *Ball* in long Pendulums, the *Bob* in ſhort ones, is the Weight at the bottom. The *Rod*, or *Wire* is plain. The terms peculiar to the *Royal Swing*, are the *Pads*, which are the Pallets in others, and are fixed on the *Spindle*. The Fork is alſo fixed on the Spindle, and about 6 inches below, catcheth hold on the Rod, at a flat piece of Braſs, called the *Flatt*, in which the lower end of the *Spring* is faſtened.

The names of the Wheels next follow The *Crown-Wheel* in Small pieces, and *Swing-Wheel* in Royal Pendulums, is that Wheel which drives the Ballance, or Pendulum.

The *Contrate-Wheel*, is that Wheel in Pocket-Watches, and others, which is next to the Crown-Wheel, whoſe Teeth and Hoop lye contrary to thoſe of other Wheels: whence it hath its Name.

The *Great Wheel*, or *Firſt-Wheel*, is that which the Fuſy, *&c.* immediately driveth. Next it, are the *Second-Wheel*, *Third-Wheel*, *&c.*

Next

Next followeth the Work between the Frame and Dial-Plate. And first, is the *Pinion of Report*; which is that Pinion, which is commonly fixed on the Arbor of the great Wheel, and in old Watches used to have commonly but four Leaves; which driveth the *Dial-Wheel*, and this carrieth about the *Hand*.

The last part which I shall speak of is the *Clock*, which is that part which serveth to strike the hours: In which I shall

First speak of the *Great*, or *First Wheel*; which is that which the Weight or Spring first drives. In 16 or 30 hour Clocks, this is commonly the *Pin-Wheel*; In 8 Day pieces, the *Second-Wheel* is commonly the *Pin-Wheel*. This Wheel thus with Pins is called the *Striking Wheel*, or *Pin-Wheel*.

Next to this Striking Wheel, followeth the *Detent-Wheel*, or *Hoop Wheel*, it having a Hoop almost round it, in which is a vacancy, at which the Clock locks.

The next is the *Third*, or *Fourth-Wheel* (according as it is distant from the First-Wheel) called also the *Warning Wheel*.

And lastly is the *Flying Pinion*, with a *Fly* or *Fan* to gather Air, and so bridle the rapidity of the Clock's motion.

Besides these, there are the *Pinion* of *Report*, of which before, which driveth round the *Locking-Wheel*, called also the *Count-Wheel*, with 11 Notches in it commonly, unequally distant from one another, to make the Clock strike the hours of 1, 2, 3, *&c.*

Thus much for the Wheels of the Clock part.

Besides which there are the *Rash*, or *Ratch*; which is that sort of Wheel, of twelve large Fangs, that runneth concentrical to the Dial-Wheel, and serveth to lift up the Detents every hour, and make the Clock strike.

The *Detents* are those Stops, which by being lifted up, or let fall down, do lock and unlock the Clock in striking.

The *Hammers* strike the Bell: The *Hammer tails* are what the Striking-pins draw back the Hammers by.

*Latches* are what lift up, and unlock the Work.

*Catches* are what hold by hooking, or catching hold of.

The *Lifting pieces* do lift up, and unlock the Detents, in the Clock part.

The *Train* is the number of Beats which the Watch maketh in an Hour, or any other certain time.

CHAP.

# CHAP. II.

## *The Art of Calculation.*

### SECT. I.

### *General preliminary Rules and Directions for Calculation.*

§ 1. FOR the more clear understanding this Chapter it must be observed, that those *Automata* (whose *Calculation* I chiefly intend) do by little Interstices, or Strokes, measure out longer portions of Time. Thus the strokes of the Ballance of a Watch, do measure out Minutes, Hours, Days, *&c.*

Now to scatter those strokes among *Wheels* and *Pinions*, and to *proportionate* them, so as to measure time regularly is the design of Calculation. For the clearer discovery of which, it will be necessary to proceed leisurely, and gradually.

§ 2. And in the first place, you are to know, that any Wheel being divi- *Oughtred of Autom. Sect.* 4.

ded by its Pinion, ſhews how many *turns* that Pinion hath to one turn of that Wheel. Thus a Wheel of 60 teeth driving a Pinion of 6, will turn round the Pinion 10 times in going round once.

From the Fuſy to the Ballance the Wheels drive the Pinions; and conſequently the Pinions run faſter, or go more turns, than the Wheels they run in. But it is contrary, from the great-Wheel to the Dial-Wheel. Thus in the laſt example, the Wheel drives round the Pinion 10 times: but if the Pinion drove the Wheel, it muſt turn 10 times to drive the Wheel round once.

§ 3. Before I proceed further, I muſt ſhew how to write down the Wheels and Pinions. Which may be done, either as Vulgar Fractions, or in the way of Diviſion in Vulgar Arithmetick. For Ex. A Wheel of 60 moving a Pinion of 5, may be ſet down thus, $\frac{66}{5}$: or rather thus 5) 60: where the firſt figure is the Pinion, the next without the hook, is the Wheel.

The number of Turns, which the Pinion hath in one turn of the Wheel, is ſet without a hook on the right hand: as 5)60(12, *i. e.* a Pinion 5 playing in a Wheel of 60, moveth round 12 times in one Turn of the Wheel.

A

4)36(9
5)55(11
5)45(9
5)40(8
17

A whole Movement may be noted thus, $\frac{4}{36}$ $\frac{55}{5}$ $\frac{45}{5}$ $\frac{40}{5}$ 17 Notches in the Crown-Wheel. Or rather as you see here in the Margin: where the uppermost number above the line, is the Pinion of Report 4, the Dial-wheel 36, and 9 turns of the Pin. of Report. The second number (under the line) is 5 the Pinion, 55 is the Great-wheel, and 11 turns of the Pinion it driveth. The third numbers, are the Second-wheel, *&c.* The fourth the Contrate wheel, *&c.* And the single number 17 under all, is the Crown wheel.

§ 4. By the § 2. before, knowing the number of turns, which any Pinion hath in one turn of the Wheel it worketh in, you may also find out how many turns a Wheel or Pinion hath, at a greater distance, as the Contrate-wheel, Crown-wheel, or *&c.* For it is but multiplying together the *Quotients*, and the number produced, is the number of Turns. An Example will make what I say plain: let us chuse these 3 numbers here set down; the first of which

5)55(11
5)45(9
5)40(8

By the Quotients I commonly mean the number of Turns; which number is set on the right hand, without a hook, as is shewn in the last Paragraph. Which I note here now once for all.

hath 11 turns, the next 9, and the last 8. If you multiply 11 and 9 it produceth 99, for 9 times 11 is 99, that is, in one turn of the Wheel 55, there are 99 turns of the second Pinion 5, or the Wheel 40, which runs concentrical, or on the same Arbor with the second Pinion 5. If you multiply 99 by the last Quotient 8 (that is, 8 times 99 is 792) it shews the number of turns, which the third and last Pinion 5 hath. So that this third, and last Pinion turns 792 times in one turn of the first Wheel 55. Another Example will make it still more plain. The example is in the Margin. The turns are 10, 9. and 8. These multiplied as before run thus, *viz.* 10 times 9 is 90, that is, the Pinion 6 (which is the Pinion of the third Wheel 40) turns 90 times in one turn of the first wheel 80. This last product 90 being multiplied by 8, produces 720; that is, the Pinion 5 (which is the Pin. of the Crown-wheel 15) turns 720 times in one turn of the first-wheel, of 80 teeth.

8)80(10
6)54(9
5)40(8
———
15

§ 5. We may now proceed to that, which is the very groundwork of all; which is, not only to find out the turns, but the Beats also of the Ballance in those turns of the Wheels. By the last

last paragraph, having found out the number of turns, which the Crown-wheel hath in one turn of the Wheel you seek for, you must then multiply those turns of the Crown-wheel by its number of Notches, and this will give you half the number of Beats, in that one turn of the wheel. Half the number, I say, for the reasons in the following 6 §. For the Explication of what hath been said, we will take the example in the last §: the Crown-wheel there, has(as hath been said) 720 turns to one turn of the the first Wheel: This number multiplyed by 15 (the Notches in the Crown-wheel,) produceth 10800, which are half the number of strokes of the Ballance, in one turn of the first wheel 80. The like may be done for any of the other Wheels; as the Wheel 54, or 40: but I shall not insist upon these,having said enough.

I shall give but one Example more, which will fully, and very plainly illustrate the whole matter. The example is in the Margin, and 'tis of a 16 hour Watch, wherein the Pinion of Report is 4, the Dial-wheel 32, the Great-wheel is 55, the Pinion

4)32)8
―――
5)55(11
5)45(9
5)40(8
―――
17

of

of the ſecond Wheel is 5, *&c.* the number of Notches in the Crown-wheel are 17: the quotients, or number of turns in each, are 8, 11, 9, 8. All which being multiplyed as before, make 6336: this number multiplyed by 17, produceth 107712; which laſt ſumm is half the number of Beats in one turn of the Dial-wheel. The half number of Beats in one turn of the Great-wheel, you will find to be 13464: For 8 times 17 is 136, which is the half number of Beats in one turn of the Contrate-wheel 40: and 9 times 136, is 1224, the half beats in one turn of the Second-wheel: and 11 times 1224, is 13464, the half beats in one turn of the Great-wheel 55. And 8 times this laſt, is 107712 before named. If you multiply this by the two Pallets, that is, double it, it is 215424, which is the number of beats in one turn of the Dial-weeel, or 12 hours. If you would know how many beats this Watch hath in an hour, 'tis but dividing the beats in 12 hours, into 12 parts, and it gives 17952, the train of the Watch, or Beats in an hour. If you divide this into 60 parts, it gives 299 and a little more, for the Beats in a minute. And ſo you may go on to ſeconds and thirds if you pleaſe.

Sir *J. Moor* Mat. Com. p. 109.

Thus I have delivered my thoughts

as

as plainly as I can, that I may be well understood; this being the very foundation of all the artificial part of Clock-work. And therefore let the young practiser exercise himself thorowly in it, in more than one example.

If I have offended the more learned, quick-sighted Reader, by using many words; my desire to instruct the most ignorant Artist, must plead my excuse.

§ 6. The Ballance or Swing hath two strokes to every tooth of the Crown-wheel. For each of the two Pallets hath its blow against each tooth of the Crown-wheel: wherefore a Pendulum that swings Seconds, hath its Crown-wheel only 30 teeth. Ibid. p. 116.

## SECT. II.

### *The way to Calculate, or contrive the Numbers of a piece of Watch-work.*

Having in the last Section led on the Reader to a general knowledge of Calculation; I may now venture him further into the more obscure and useful parts of that Art: which I shall explain with all possible plainness, tho less brevity, than I could wish.

§ 1.

*Oughtred* Autom. Sect. 14. § 1. The ſame motion may be performed either with one Wheel and one Pinion; with by many Wheels and many Pinions: provided that the number of turns of all thoſe Wheels bear the ſame proportion to all thoſe Pinions, which that one Wheel bears to its Pinion. Or (which is the ſame thing) that the number produced by multiplying all the Wheels together, be to the number produced by multiplying all the Pinions together, as that one Wheel is to that one Pinion. Thus ſuppoſe you had uſe for a Wheel of 1440 teeth with a Pin. of 28 leaves, you may make it into 3 Wheels and Pinions, *viz.* 4)36, 7)8, 1)5. For if you multiply the three Wheels together, *viz.* 36, 8 and 5; and the three Pinions together by themſelves, *viz.* 4, 7 and 1, you will find 1440 to ariſe for the Wheels, and 28 for the Pinions. Or if you try the example by the number of turns, it will be the ſame. For 28 ) 1440 ($51\frac{3}{7}$. And the quotients and turns of the 3 Wheels and Pinions multiplyed together, are $51\frac{3}{7}$ alſo, as in the laſt example.

28)1440

*See Sect.* 1. § 3.

*Sect.* 1. § 4.

It matters not in what order the Wheels and Pinions are ſet, or which Pinion runs in which Wheel: Only for convenience ſake, they commonly

ſet

ſet the biggeſt numbers to drive the reſt.

§ 2. Two Wheels and Pinions of different numbers may perform the ſame motion. As, a Wheel of 36 drives a Pinion of 4, all one as a Wheel of 45 drives a Pin. of 5; or as a Wheel of 90 drives a Pin. of 10. The turns of each are 9. *Ought. ib.*

§ 3. If in breaking your Train into parcels (of which by and by) any of your Quotients ſhould not pleaſe you; or if you would alter any other two numbers which are to be multiplyed together, you may vary them by this Rule: Divide your two numbers by any two other numbers which will meaſure them; and then multiply the Quotients by the alternate diviſors, the product of theſe two laſt numbers found, ſhall be equal to the product of the two numbers firſt given. Thus if you would vary 36 times 8, divide theſe by any two numbers that will evenly meaſure them, as 36 by 4, and 8 by 1. The fourth part of 36 is 9, and 8 divided by 1 gives 8. Multiply 9 by 1, the product is 9; and 8 multiplyed by 4 produceth 32. So that for 36 times 8 you ſhall have found 32 times 9. The operation is in the Margin, that you may ſee, and apprehend it *Id. ib.*

$$\begin{array}{ccc} 9 & & 8 \\ 36 & \times & 8 \\ \underline{4} & & \underline{1} \\ 32 & \times & 9 \end{array}$$

it the better. These numbers are equal, *viz.* 36 times 8 is equal to 32 times 9; both producing 288. If you divide 36 by 6, and 8 by 2, and multiply as before is said, you will have for 36 times 8, 24 times 12, equal to 288 also.

If this Rule seem to the unskilful Reader hard to be understood, let him not be discouraged, because he may do without it, altho it may be of good use to him that would be a more compleat Artist.

§ 4. Because in the following Paragraphs, I shall have frequent occasion to use the Rule of Three, or Rule of Proportion, it will be necessary to shew the unskilful Reader how to work this noble Rule.

If you find 3 or 4 numbers thus set, with four spots after the second of them, 'tis the Rule of Proportion: as in this example, 2.4 :: 3.6. *i. e.* As 2 is to 4 : So is 3 to 6.

The way to work this Rule, *viz.* by the 3 first numbers to find a fourth, is, to multiply the second number and the third together, and divide their product by the first. Thus 4 times 3 is 12, which 12 divided by 2, gives 6; which is the number sought for, and stands in the fourth place.

You will find the great use of this Rule

Rule hereafter; only take care to bear it in mind all along.

§ 5. To proceed. If in ſeeking for your Pinion of Report, or by any other means you happen to have a Wheel and Pinion fall out with croſs numbers, too big to be cut in Wheels, and yet not to be altered by the former Rules, you may find out two numbers of the ſame, or a near proportion, by this following Rule, *viz.* As either of the 2 numbers given, is to the other :: So is 360 to a fourth: Divide that fourth number, as alſo 360 by 4. 5. 6. 8. 9. 10. 12. 15. (each of which numbers doth exactly meaſure 360) or by any one of thoſe numbers that bringeth a quotient neareſt to an integer (or whole nmuber.) Thus if you had theſe two numbers, 147 the Wheel, and 170 the Pinion, which are too great to be cut in ſmall Wheels, and yet can't be reduced into leſs becauſe they have no other common meaſure, but unity: ſay therefore according to the laſt paragraph, As 170 is to 147; or as 147 is to 170 :: So is 360 to a fourth number ſought. In numbers thus, 170. 147 :: 360. 311. or 147. 170 :: 360. 416. Divide the fourth number and 360 by one of the foregoing numbers; as 311 and 360 by 6, it gives 52 and 60. In numbers 'tis thus,

Id. Ib.

*See* § 4.

(9

$6)\begin{matrix}311(52\\360(60\end{matrix}$ Divide by 8 'tis thus, $8)\begin{matrix}311(39\\360(45\end{matrix}$

If you divide 360 and 416 by 8, it will fall out exactly to be 45 and 52 $8)\begin{matrix}460(45\\316(52\end{matrix}$

Wherefore for the two numbers 147 and 170, you may take 52 and 60; or 39 and 45; or 45 and 52, or *&c.*

§ 6. I shall add but one Rule more before I come to the practice of what hath been laid down; which Rule will be of perpetual use, and consists of these five particulars.

Oughtred Sect. 12. Sir *J. Moor* Ibid. p. 109.

1. *To find what number of turns the Fusy will have*, thus, As the Beats of the Ballance in one turn of the Great Wheel or Fusy (suppose 26928) To the Beats of the Ballance in one hour (suppose 20196) :: So is the continuance of the Watches going in hours (suppose 16) to the number of the turns of the Fusy 12. In numbers 'twill stand thus, 26928. 20196 :: 16. 12. By § 4. you may remember that you are to multiply 20196 by 16, the product is 323136: Divide this by 26928, and there will arise 12 in the Quotient, which must be plac'd in the fourth place, and is the number of turns which the Fusy hath.

2. By

2. *By the Beats and turns of the Fusy, to find how many hours the Watch will go,* thus,

As the Beats of the Ballance in one hour, are to the Beats in one turn of the Fusy :: So is the number of the turns of the Fusy, to the continuance of the Watches going. In numbers thus,

20196. 26928 :: 12. 16.

3. *To find the strokes of the Ballance in one turn of the Fusy*, say, As the number of turns of the Fusy, to the continuance of the Watch's going in hours :: So are the Beats in one hour, to the Beats of one turn of the Fusy. In numbers it is thus,

12. 16 :: 20196. 26928.

4. *To find the Beats of the Ballance in an hour*, say thus, As the hours of the Watch's going, to the number of turns of the Fusy :: So are the Beats in one turn of the Fusy, to the Beats in an hour. In numbers thus,

16. 12 :: 26928. 20196.

5. *To find what Quotient is to be laid upon the Pinion of Report*, say thus, As the Beats in one turn of the Great-wheel, to the beats in an hour :: So are the hours of the Face of the Clock (*viz.* 12 or 24) to the Quotient of the Hour-wheel or Dial-wheel, divided by the

the Pinion of Report, *i. e.* the number of turns, which the Pinion of Report hath in one turn of the Dial-wheel. In numbers thus,

26928. 20196 :: 12. 9.

Or rather (to avoid trouble) say thus, As the hours of the Watch's going, are to the numbers of the turns of the Fusy :: So are the hours of the Face, To the Quotient of the Pinion of Report. In numbers thus, 16. 12 :: 12. 9. If the hours of the Face be 24, the Quotient will be 18; thus, 16. 12 :: 24. 18.

*N. B.* This Rule may be made serve to lay the Pin. of Report on any other wheel thus, As the Beats in one t. of any wheel to the Beats in an hour :: So are the hours of the Face, or Dial-plate of the Watch, to the Quotient of the Dial-wheel divided by the Pinion of Report, fixed on the Spindle of the aforesaid Wheel.

§ 7. Having given a full account of all things necessary to the understanding the Art of Calculation, I shall now reduce what hath been said into practice, by shewing how to proceed, in Calculating a piece of Watch-work.

The first thing you are to do, is to pitch upon your Train, or Beats of the Ballance in an hour: as, whither a swift Train, about 20000 beats (which

is

is the usual Train of a common 30 hour Pocket-Watch) or a slower Train of about 16000 (the Train of the new Pendulum Pocket-Watches ;) or any other Train.

Having thus pitched upon your Train, you must next resolve upon the number of turns you intend your Fusy shall have, and also upon the number of Hours, you would have your Piece to go: As suppose 12 turns; and to go 30 hours, or 192 hours (which is 8 days) or *&c.*

These things being all soon determined; you next proceed to find out the beats of the Ballance, or Pendulum, in one turn of the Fusy, by the last § 6. part 3. *viz.* As the turns of the Fusy, to the Hours of the Watch's going :: So is the Train, To the number of beats in one turn of the Fusy. In numbers thus, 12. 16 : : 20000. 26666. §. 4.
Which last number are the beats in one turn of the Fusy, or Great-wheel; and (by Sect. I. § 5. of this Chap.) are equal to the Quotients of all the Wheels unto the Ballance multiplied together. This number therefore is to be broken into a convenient parcel of Quotients: which you are to do after this manner. First, half your number of beats, *viz.* 26666, for the reasons in Sect. I. § 6. of this Chap. the half whereof is 13333.

Next

Next you are to pitch upon the number of your Crown-wheel, as ſuppoſe 17. Divide 13333 by 17, the Quotient will be 784 (or to ſpeak in the language of one that underſtands not Arithmetick, divide 13333 into 17 parts, and 784 will be one of them.) This 784 is the number left for the Quotients (or turns) of the reſt of the Wheels and Pinions: which being too big for one or two Quotients, may be beſt broken into three. Chuſe therefore 3 numbers, which when multiplied all together continually will come neareſt 784. As ſuppoſe you take 10, 9, and 9. Now 10 times 9 is 90; and 9 times 90 is 810, which is ſomewhat too much. You may therefore try again other numbers, as ſuppoſe 11, 9, and 8. Theſe multiplied as the laſt, produce 792, which is as near as can be, and convenient-Quotients.

Thus you have contrived your piece, from the Great Wheel to the Ballance. But the numbers not falling out exactly, according as you at firſt propoſed, you muſt correct your work thus. Firſt, to find out the true number of beats, in one turn of the Fuſy, you muſt multiply 792 aforeſaid, (which is the true product of all the Quotients you pitched upon,) by 17, the notches of the Crown-wheel; the product of this is

13464,

13464, which is half the number of true beats in one turn of the Fusy, by Sect. I. § 5. of this Chap. Then to find the true number of beats in an hour, say by § 6. part 4. of this Sect. As the hours of the Watch's going, *viz.* 16, to the 12 turns of the Fusy :: So is 13464 the half beats in one turn of the Fusy, to 10098 the half beats in an hour: the numbers will stand thus 16. 12 :: 13464. 10098.

Then to know what Quotient is to be laid upon the Pinion of Report, say by § 6. part 5. of this Sect. As the hours of the Watch's going, *viz.* 16, to the turns of the Fusy, *viz.* 12 :: So are the hours of the Dial-plate, *viz.* 12, To the Quotient of the Pinion of Report fixed on the Great-wheel. In numbers thus, 16. 12 :: 12. 9.

| | |
|---|---|
| 4)36(9 | Having thus found out all your Quotients, 'tis easie |
| ——— | to determine what numbers |
| 5)55(11 | your Wheels shall have: for |
| 5)45(9 | chuse what numbers your |
| 5)40(8 | Pinions shall have, and mul- |
| ——— | tiply the Pinions by their |
| 17 | Quotients, and that pro- duceth the number for your |

Wheels, as you see in the Margin. Thus 4 is the number of your Pinion of Report, and 9 its quotient; therefore 4 times 9, which makes 36, is the number

number for the Dial-wheel. So the next Pinion being 5, and its quotient 11, this multiplied produces 55 for the Great-wheel. And the like of the rest of the following numbers.

Thus, as plain as words can express it, I have shewed how to calculate the number of a 16 hour Watch.

Oughtred Sect. 21.

§ 8. This Watch may be made to go a longer time, by lessning the Train, and altering the Pinion of Report. Suppose you could conveniently slacken the Train to 16000, the half of which is 8000. Then say (by § 6. part 2. of this Sect.) As the halfed Train, or Beats in an hour, *viz.* 8000, to the half beats in one turn of the Fusy, *viz.* 13464 : : So are the turns of the Fusy, *viz.* 12, To the hours of the Watch's going: in numbers thus, 8000. 13464 : : 12. 20. So that this Watch will go 20 hours.

Then for the Pinion of Report, say, by the same §, part 5, As (20 the continuance;) To 12 (the turns of the Fusy):: So are 12 (the hours of the Face,) To 7, the quotient of the Pinion of Report. In numbers thus, 20. 12 : : 12. 7.

| | |
|---|---|
| 4)28(7 | The work is the same as before, as to the numbers; only the Dial-wheel is but 28, because its quotient is altered to 7; as appears in the Margin, by the Scheme of the work. |
| 5)55)11 | |
| 5(45(9 | |
| 5)40(8 | |
| 17 | |

§ 9. I shall give the Reader one example more, for the sake of shewing him the use of some of the foregoing rules, not yet taken notice of in the former operations. Suppose you would give numbers to a Watch of about 10000 beats in an hour, to have 12 turns of the Fusy, to go 170 hours, and 17 notches in the Crown-wheel. *Id. ib.* § 29.

This work is the same as in the last Example § 7. In short therefore thus, As the turns 12 : are to the Continuance 170 : : So is the Train 10000, To 141666, which are the beats in one turn of the Fusy. The numbers will stand thus, 12. 170 : : 10000. 141666. Half this last is 70833. Divide this half into 17 parts, and 4167 will be for the quotients. And because this number is too big for 3 quotients, therefore chuse 4: as suppose 10, 8, 8, and 6 $\frac{3}{5}$ (*i. e.* 6 and 3 fifths.) These multiplied together as before, and with 17, maketh 71808, which are half the true beats in one turn of the Fusy. By this you are to find out your

C true

true Train first, saying in the former example, as 170 to 12 :: So 71808, to 5069; which last is the half of the true Train of your Watch. Then for the Pinion of Report, say, as 170 to 12 :: So 12 to $\frac{144}{170}$. Which Fraction ariseth thus: If you multiply 12 by 12 it makes 144; and divide 144 by 170, you cannot; but setting the 144 (the dividend) over 170, (the Divisor) and there ariseth this fraction $\frac{144}{170}$, which is a Wheel and Pinion; the lower is the Pinion of Report, and the upper is the Dial-wheel, according to Sect. 1. § 3. of this Chapter. Or (which perhaps will be more plain to the unlearned Reader) you may leave those two numbers in their Divisional posture thus, 170) 144, which does express the Pinion and and Wheel, in the way I have hitherto made use of.

*Sect.* 1. § 3.

But to proceed. These numbers being too big to be cut in small Wheels, may be varied, as you see a like example is § 5. of this Section, *viz.* say, as 144. is to 170 :: So is 360, To 425. Or as 170, to 144 :: So is 360, To 305. In numbers thus, 144. 170 :: 360. 425. Or 170. 144 :: 360. 305. Divide 360, and either of these two fourth and last numbers by

$$
\begin{array}{l}
24(20(\frac{20}{24} \\
\hline
6)60(10 \\
6)48(8 \\
5)40)8 \\
5)33(6\frac{3}{5} \\
\hline
\quad\quad 17
\end{array}
$$

4, 5, 6, 8, *&c.* (as is directed in the Rule last cited.) If you divide by 8, you will have for your numbers $\frac{144}{170}$ $\frac{45}{53}$ or $\frac{38}{45}$. If you divide by 15 (which will not bring it so near an integer) you will have $\frac{24}{28}$ or $\frac{20}{24}$: which last are the numbers set down in the Margin; where the numbers of the whole movement are set down.

§ 10. Having said enough, I think, concerning the Calculation of ordinary Watches, to shew the hour of the day: I shall next proceed to such as shew minutes and seconds. The process whereof is thus; first, having resolved upon your beats in an hour, you are next to find how many beats there will be in a minute, by dividing your designed Train into 60 parts. And accordingly you are to find out such proper numbers for your Crown-wheel, and quotients, as that the Minute-wheel shall go round once in an hour, and the Second-wheel once in a minute.

An Example will make all plain. Let us choose a Pendulum of 6 inches to go 8 days, with 16 turns of the Fusy. By Mr *Smith*'s Tables, a Pendulum of 6 inches vibrates 9368 in an hour. Horol. disq.
This divided by 60 gives 156 beats for a minute. Half these summs are 4684 and 78. Now the first work is to break Sect. 1. §. 6.

 this

this 78 into good proportions; which will fall into one quotient, and the Crown-wheel, First, for the Crown-wheel; let it have 15 notches. Divide 78 aforesaid by this 15, the quotient will be 5. And so this first work is done; for a Crown-wheel of 15, and a Wheel and Pinion, whose quotient is 5 (as in the Margin) will go round in a Minute, to carry a Hand to shew *Seconds*.

8)40(5

15

Next for a hand to go round in an hour to shew minutes. Now because there are 60 minutes in a hour, 'tis but breaking 60 into two good quotients (which may be 10 and 6, or 8 and $7\frac{1}{2}$, or *&c.*) and the work is done.

8)64(8
8)60($7\frac{1}{2}$
8)40(5

15

Thus your number 4684 is broken, as near as can be, into proper numbers.

But because it does not fall out exactly into the above-mentioned numbers, you must correct (as you were directed before) and find out the true number of beats in an hour, by multiplying 15 by 5, which makes 75; and this by 60 makes 4500: which is the half of the true Train. Then to find out the beats in one turn of the Fusy, operate as before, *viz.* As the num-

number of turns, 16, to the continu- § 6. Par
ance 192 : : So is 4500 to 54000, which 3. § 7.
are half the beats in one turn of the
Fusy. In numbers thus, 16. 192 : :
4500. 54000. This 54000 must be divided by 4500 which are the true numbers already pitched upon, or beats in an hour. The quotient of this division is 12, which being not too big for one single quotient, needs not be divided into more. The work will stand, as you see in the Margin.

9) 108 (12
8) 64 (8
8) 60 (7½
8) 40 (5

) 15

) 4 (8

As to the Hour-hand, the Great-wheel, which performs only one revolution in 12 turns of the Minute-wheel, will shew the hour. Or rather you may order it to be done by the Minute-wheel, as shall be shewed hereafter.

§ 11. I shall add but one example more, and so conclude this Section; and that is, to calculate the numbers of a Piece whose Pendulum swings Seconds, to shew the hour, minutes, and seconds, and to go 8 days; which is the usual performance of those Movements called *Royal Pendulums* at this day. First, cast up the number of seconds in 12 hours (which are the beats in one turn of the Great-wheel.) These are 12 times 60 minutes, and 60 times that, *Sir* J. Moor *ibid* p. 116.

gives 43200, which are the seconds in 12 hours. Half this number (for the reasons before) is 21600. The Swing-wheel must needs be 30 to swing 60 seconds in one of its revolutions. Divide 21600 by it, and 720 is the quotient, or number left to be broken into quotients. Of these quotients, the first must needs be 12 for the Great-wheel, which moves round once in 12 hours. Divide 720 by 12, the quotient is 60; which may be conveniently broken into two quotients, as 10 and 6, or 5 and 12, or 8 and 7 ½, which last is most convenient. And if you take all the Pinions 8, the work will stand as in the Margin.

v. Sect. 1. § 6.

8)96(12
8)64(8
8)60(7½
30

According to this computation, the Great-wheel will go about once in 12 hours, to shew the hour, if you please: the second-wheel once in an hour, to shew the minutes; and the Swing-wheel once in a minute, to shew the seconds.

Thus I have endeavoured with all possible plainness, to unravel this most mysterious, as well as useful part of Watch-work. In which, if I have offended the more learned Reader, by unartificial terms, or multitude of words, I desire the fault may

may be laid upon my earnest intent to condescend to the meanest capacity.

## SECT. III.

*To Calculate the Striking part of a Clock.*

§ 1. ALtho this part consists of many Wheels and Pinions, yet respect needs to be had only to the *Count-wheel*, *Striking-wheel*, and *Detent-wheel* which move round in this proportion; The Count wheel moveth round commonly once in 12, or 24 hours. The Detent-wheel moves round every stroke the Clock striketh, sometimes but once in two strokes. From whence it follows,

1. That as many Pins as are in the Pin-wheel, so many turns hath the Detent-wheel, in one turn of the Pin-wheel. Or (which is the same) the Pins of the Pin-wheel are the quotient of that Wheel, divided by the Pinion of the Detent-wheel. But if the Detent-wheel moveth but once round in two strokes of the Clock, then the said Quotient is but half the number of Pins.

2. As many turns of the Pin-wheel as are required to perform the strokes of 12 hours (which are 78) So many turns must the Pinion of Report have, to

turn round the Count-wheel once. Or thus, Divide 78 by the number of ſtriking pins, and the Quotient thereof ſhall be the Quotient for the Pinion of Report, and the Count Wheel. All this is, in caſe the Pinion of Report be fixed to the arbor of the Pin-wheel, as is very commonly done.

All this I take to be very plain: or if it be not, the example in the Margin will clear all difficulties. Here the Locking wheel is 48, the Pinion of Report is 8, the Pin-wheel is 78, the Striking-pins are 13. And ſo of the reſt. I need only to remark here, that 78 being divided by the 13 pins, gives 6; which is the Quotient of the Pinion of Report: as was before hinted.

8)48(6

———

6)78(13 pins
6)60(10
6)48(8

As for the *Warning-Wheel* and *Flying Pinion*, it matters little what numbers they have, their uſe being only to bridle the rapidity of the motion of the other Wheels.

Beſides the laſt obſervation, there are other ways to find out the Pinion of Report, which will fall under the next §.

§ 2. Theſe following Rules will be of great uſe in this part of Calculation, *viz.*

*Rule*

*Rule* 1. *To find how many strokes the Clock striketh in one turn of the Fusy or Barrel.* As the number of turns of the Great-wheel, or Fusy;

. To the days of the Clocks continuance:

:: So is the number of strokes in 24 hours, *viz.* 156,

. To the strokes in one turn of the Fusy, or Great-wheel.

*Rule* 2. *To find how many days the Clock will go.* As the number of strokes in 24 hours, which are 156,

. To the strokes in one turn of the Fusy or Great-wheel;

:: So are the turns of the Fusy, or Great-wheel,

. To the days of the Clocks continuance, or going.

*Rule* 3. *To find the number of turns of the Fusy or Barrel.* As the strokes in one turn of the Fusy;

. To the strokes of 24 hours, *viz.* 156.

:: So is the Clock's continuance,

. To the number of turns of the Fusy, or Great-wheel.

These two last Rules are of no great use (as the first is) but may serve to correct your work, if need be, when in breaking your Strokes into Quotients (of which presently) you cannot come near the true number, but a good many strokes are left remaining.

In this case, by Rule 2. you may find whether the continuance of your Clock be to your mind. And by Rule 3, you may enlarge or diminish the number of turns for this purpose. The praxis hereof will follow by and by.

The 2 following rules are to find fit numbers for the Pinion of Report, and the Locking-wheel, besides what is said before § 1. Inference 2.

Rule 4. *To fix be Pin. of Report on the Spindle of the Great-wheel.* As the number of Strokes in the Clock's continuance, or in all its turns of the Fusy,

. To the turns of the Fusy,

∴ So are the strokes in 12 hours, which are 78,

. To the Quotient of the Pinion of Report, fixed upon the arbor of the Great-wheel.

But if you would fix it to any other Wheel, you may do it thus, as is before hinted, *viz.*

§ 1. *inf.* 2.

*Rule* 5. First find out the number of Strokes in one turn of the Wheel you intend to fix your Pinion of Report upon (which I shall shew you how to do in the following §.) Divide 78 by this number, and the number arising in the Quotient, is the Quotient of the Pinion of Report.

Or thus. Take the number of strokes in one turn of the Wheel, for the num-

ber

ber of the Pinion of Report, and 78 for the Count (or Locking) wheel, and vary them to lesser numbers, by Sect. 2 § 5. of this Chapter.

The foregoing rules are of greatest use, in Clocks of a larger continuance; altho, where they can be applyed, they will indifferently serve all. But the Rule following (which will serve larger Clocks too) I add chiefly for the use of lesser pieces, whose continuance is accounted by hours.

This Rule is to find the strokes in the Clock's continuance, *viz.* As 12, is to 78 :: So are the hours of the Clocks continuance, to the number of strokes in that time. *Rule 6.*

This Rule (I said) may be made use of for the largest Clock; but then you must be at the trouble of reducing the Days into Hours. Whereas the shortest way is to multiply the strokes in one turn of the Great-wheel, by the number of Turns of the Fusy. Thus in an 8 day piece, the strokes in one turn are 78. These multiplied by 16, (the Turns) produce 1248; which are the Srokes in the Clock's continuance. If you work by the foregoing rule, the hours of 8 days are 192. Then say, 12. 78 :: 192. 1248.

§ 3. In this Paragraph, I shall shew the use of the preceeding Rules, and by

by examples make all plain that might seem obscure in them.

I begin with small Pieces: of which but briefly. And first, having pitched upon the number of turns, and the continuance of your Clock, you must find, by the last rule, how many strokes are in its continuance. Then (if you make the Great-wheel the Pin-wheel) divide these strokes by the number of turns, and you have the number of Striking-pins. Or divide by the number of Pins, and you have the number of Turns.

Thus a Clock of 30 hours, with 15 turns of the Great-wheel, hath 195 strokes. For by the last Rule, 12. 78 :: 30. 195. Divide 195 by 15, it gives 13 for the striking pins. Or if you chuse 13 for your number of Pins, and divide 195 by it, it gives 15, for the number of turns, as you see in the Margin.

15)195(13

13)195(15

As for the Pin of Report, and the rest of the Wheels, enough is said in the § 1.

But suppose you would calculate the numbers of a Clock of much longer continuance, which would necessitate you to make your Pin-wheel further distant from the Great wheel, you are to proceed thus: Having resolved upon your turns, you must find out the

the number of strokes in one turn of the Great-wheel, or Fusy, by § 2. Rule 1. Thus in an 8 day piece, of 16 turns, 16. 8 : : 156. 78. So in a piece of 32 days, and 16 turns, 16. 32 : : 156. 312. (See the operation of these numbers in the Rule referred unto.) These strokes so found out, are the number which is to be broken into a convenient parcel of Quotients, thus ;

First resolve upon your number of Striking-pins : divide the last named number by it : the quotient arising hence, is to be one, or more quotients, for the Wheels and Pinions. As in the last examples, divide 78 by 8 (the usual pins in an 8 day piece) and the quotient is $9\frac{3}{4}$ ; which is a quotient little enough. So in the Month-piece : if you take your Pins 8, divide 312 by it, the quotient is 39. Which being too big for one, must be broken into two quotients, for Wheels and Pinions, or as near as can be : which may be 7 and 5, or 6 and $6\frac{1}{2}$. The latter is exactly 39, and may therefore stand : as you see in the Margin.

10)65(6½
8)48(6
6)48(8 pins

The quotients being thus determined, and accordingly the Wheels and Pinions, as you see ; the next work is to find a quotient for the Pinion of Report

Report; to carry round the Count (or Locking) wheel once in 12 hours, or as you please. If you fix your Pinion of Report on the Great wheel arbor, you must operate by the Rule 4. of the last Paragraph. As in the last example of the Month-piece: by Rule 6. before, the strokes in the continuance are 4992. Then by Rule 4 say, 4992. 16 :: 78 $\frac{4992}{1248}$; or thus 4992(1248. The first of which two numbers is the Pinion, the next is the Wheel. Which being too large, may be varied to $\frac{36}{9}$ or 36)9; or to $\frac{24}{6}$ or 24)6, by Sect. 2. § 5. before.

These numbers being not the usual numbers of a Month-piece, but only made use of by me, as better illustrating the foregoing rules; I shall therefore, for the fuller explication of what has been said, briefly touch upon the calculation of the more usual numbers. They commonly increase the number of Striking-pins, and so make the Second-wheel the Striking-wheel: Suppose you take 24 Pins; divide 312 by it, and the Quotient is 13. Which is little enough for one Quotient; and may therefore stand as you see is done in the Margin: where the Quotient of the first Wheel is 13. In the second Wheel

8)104(13

6) 72(12.24 pins

Wheel of 72 teeth, are the 24 pins, altho its quotient is but 12, because the Hoop-wheel is double, and goes round but once in two strokes of the Pin-wheel.

The Pinion of Report here, is the same with the last, if fixed upon the arbor of the Great-wheel. But if you fix it on the arbor of the second, or Pin-wheel, its quotient then is found by § 1. Infer. 2. or by § 2. Rule 5. *viz.* Divide 78 by 24, and the number arising in the quotient, is the quotient of the Pinion of Report, which is $3\frac{3}{4}$. The Pinion of Report then being 12: the Count-wheel will be 39, as in the Margin.

$12)39(3\frac{1}{4}$

To perfect the Reader in this part of Calculation, I wil finish this Section with the calculation of a Year-piece of Clock-work. The Process whereof is the same with the last, and therefore I may be more brief with this, except where I have not touched upon the foregoing rules.

We will chuse a piece to go 395 days with 16 turns, and 26 Striking-pins. By § 2. Rule 1. there are 3851 strokes in one turn of the Great-wheel. For 16. 395 :: 156. 3851. This last number divided by the 26 pins, leaves 148 in the quotient, to be broken into two

*Sect.* 2. §. 4.

or

or more quotients, for Wheels and Pinions. These quotients may be 12 and

| | |
|---|---|
| 10) 120 ( 12 | 12; which multiplied, makes 144, which |
| 8) 96 ( 12 | is as near as can well |
| 78 \| 26 pins | be to 148. The work thus far contrived, |

will stand as you see in the Margin.

Before you go any further, you may correct your work, and see how near your numbers come to what you proposed at first, because they did not fall out exact, and first, for the true continuance of your Clock: *If you multiply* 12, 12, *and* 26 ( i. e. *the Quotients and the Striking pins) you have the true number of Strokes, in one turn of the Great-wheel:* Which, in this example, make 3744. For 12 times 12 is 144; and 26 times that, is 3744. (This Direction I would have noted, and remembred, as a Rule useful at any time to discover the nature of any piece of Clock work.) Having thus the true number of Strokes desired, by § 2. Rule 2. you may find the true Continuance to be only 384 days. For 156 3744 :: 16. 384. If this Continuance doth not please you, you may come nearer to your first proposed number of 395 days, by a small encrease of the number of Turns, according to § 2. Rule 3. *viz.* by making your turns almost 16 $\frac{1}{2}$. For 3744 156 :: 395. 16 $\frac{1}{2}$ almost. Lastly

Lastly, For the Pinion of Report, if you fix it upon the Great-wheel, it will require an excessive number: if you fix it upon the Pin-wheel (which is usual) then by § 2. Rule 5.

13)39(3 the quotient is 3; and the Pinion of Report being 13, the Count-wheel will be 39; as you see in the Margin.

But for the better exercising the Reader, let us fix it upon the Spindle of the 2d-wheel 96. Its quotient is 12; which multiplied by 26 (the pins) produceth 312; which are the strokes in one turn of that Second-wheel. Then by § 2. Rule 5, divide 78 by 312. *i. e.* Set them as a Wheel and Pinion thus, 312)78, and vary them to lesser numbers by Sect. 2. § 5. ) *viz.* 36)9, or to 24)6 or the like.

I think it needless to say any thing of Pocket Clocks, whose calculation is the very same, with what goes before.

That the unlearned Reader may not think any thing going before difficult, I need only to advise him, to look over the working of the Rule of Proportion, in Sect. 2. § 4. For I think all will be plain, if that be well understood.

SECT.

## SECT. 4.

### *Of Quarters and Chimes.*

THE Reader will expect that I should say somewhat concerning Quarters and Chimes: but because there is little, but what is purely mechanical in it, I shall say the less, and leave the Reader to his own invention.

§ 1. The *Quarters* are generally a distinct part from the Clock part, which striketh the Hour.

The *Striking-Wheel* may be the First, Second, or *&c.* Wheel according to your Clock's continuance. Unto which Wheel you may fix the Pinion of Report.

The *Locking-Wheel* must be divided (as other Locking-Wheels) into 4,8, or more unequal parts, so as to strike the Quarter, and lock at the first Notch; the half-hour, and lock at the second Notch, *&c.* And in doing this, you may make it to chime the Quarters, or strike them upon two Bells, or more.

'Tis usual for the Pin-wheel, or the Locking-wheel, to unlock the Hour-part in these Clocks; which is easily done by some jogg or latch, at the end of the last Quarter, to lift up the Detents of the Hour-part.

If you would have your Clock ſtrike the Hour, at the Half hour, as well as whole Hour, you muſt make the Locking wheel of the Hour-part double: *i.e.* it muſt have two Notches of a ſort, to ſtrike 1, 2, 3, 4, *&c.* twice apiece.

§ 2. As for *Chimes*, I need ſay nothing of the Lifting-peices and Detents, to lock and unlock; nor of the Wheels to bridle the motion of the Barrel. Only you are to obſerve, that the Barrel muſt be as long in turning round, as you are in Singing the Tune it is to play. As for the *Chime-Barrel*, it may be made up of certain Barrs, that run athwart it, with a convenient number of holes punched in them, to put in the Pins, that are to draw each Hammer. By this means you may change the Tune, without changing the Barrel. This is the way of the *Royal Exchange* Clock in *London*, and of others. In this caſe, the Pins, or Nuts which draw the Hammers muſt hang down from the Bar, ſome more, ſome leſs, and ſome ſtand upright in the Bar: the reaſon whereof is, to play the time of the Tune rightly. For the diſtance of each of theſe Bars, may be a Semi-breif, or *&c.* of which hereafter.

But the moſt uſual way is, to have the Pins that draw the Hammers, fixed

on

on the Barrel. For the placing of which Pins you may make uſe of the the Muſical Notes, or proceed by the way of Changes on Bells, *viz.* 1, 2, 3, 4, *&c.* The firſt being far the better way, I ſhall ſpeak of that chiefly, eſpecially becauſe the latter will fall in to be explained with it.

And firſt, you are to obſerve what is the Compaſs of your Tune, or how many Notes or Bells there are from the higheſt to the loweſt: and accordingly you muſt divide your Barrel from end to end. Thus in the examples following, each of thoſe Tunes are 8 notes in compaſs; and accordingly the Barrel is divided into 8 parts. Theſe Diviſions are ſtruck round the Barrel, oppoſite to which are the Hammer-tails.

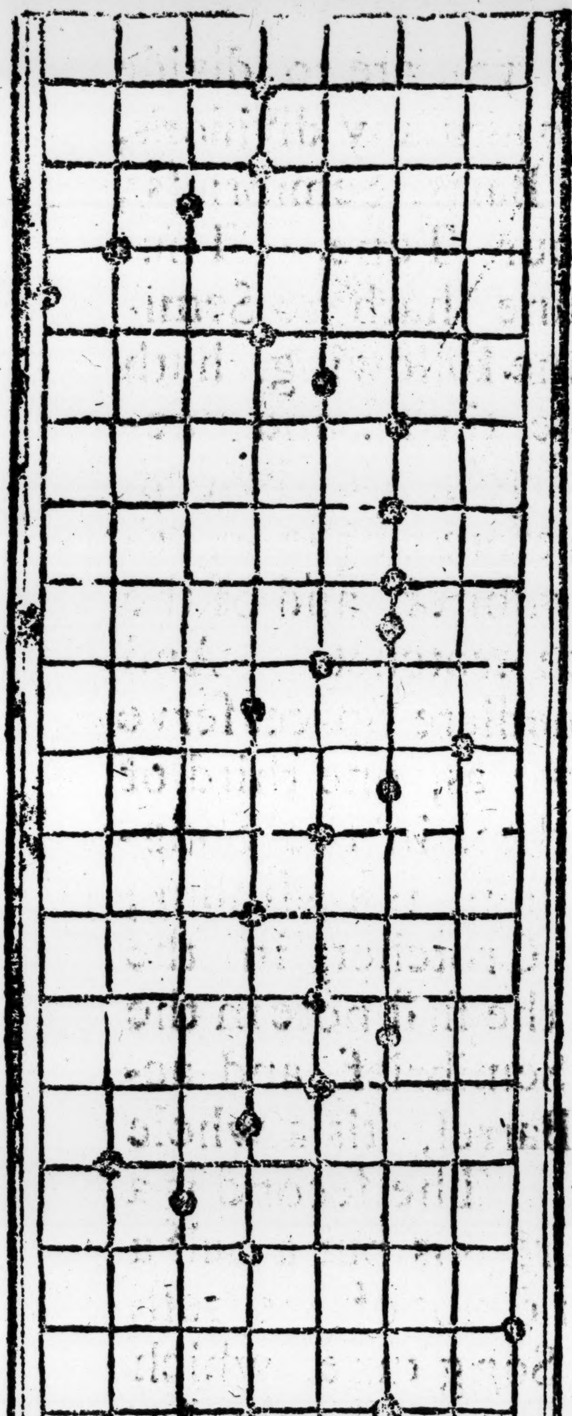
I ſpeak here, as if there was only one Hammer to each Bell, that the Reader may more clearly apprehend what I am explaining. But when two Notes of the ſame ſound come together in a Tune, there muſt be two Hammers to that Bell, to ſtrike it. So that if in all the Tunes you intend to Chime, of 8 notes compaſs, there ſhould happen to be ſuch double notes on every Bell, inſtead of 8, you muſt have 16 Hammers: and accordingly you muſt divide your

your Barrel, and ſtrike 16 ſtrokes round it oppoſite to each Hammer-tail. Thus much for dividing your Barrel from end to end.

In the next place, you are to divide it (round about) into as many diviſions, as there are muſical Barrs, Semibriefs, Minums, *&c.* in your Tune. Thus the 100th Pſalm-tune hath 20 Semibriefs; the Song-tune following, hath 24 Barrs of triple time: and accordingly their Barrels are divided. Each diviſion therefore of the 100th Pſalm Barrel is a Semibrief, and of the Song-tune 'tis three crotchets. And therefore the intermediate Spaces ſerve for the ſhorter notes: as, one third of a diviſion, is a Crochet, in the Song-tune. One half a diviſion, is a Minum; and one quarter, a Crotchet, in the Pſalm-tune. Thus the firſt note in the 100th Pſalm, is a Semibrief, and accordingly on the Barrel, 'tis a whole diviſion from 5 to 5. The ſecond is a Minum, and therefore 6 is but a half a diviſion from 5; and ſo of the reſt. And ſo alſo for the Song tune, which is ſhorter time: the two firſt notes being Quavers, are diſtant from one another, and from the third pin, but half a third part of one of the diviſions. But the two next pins (of the bell 3, 3) being Crotchets, are diſtant ſo many

**A Table of Chimes to the 100 Psalm.**

8 7 6 5 4 3 2 1 87654321



The Musical Notes of Psalm 100.

many third parts of a division. And the next Pin (of the bell 1) being a Minum, is distant from the following pin (4) two thirds of a division.

From what hath been said, you may conceive the surface of a chime-barrel to be represented in the Tables following, as stretcheth out at length: or (to speak plainer) that if you wrap either of these Tables round a Barrel, the Dots in the Table, will shew the places of the Pins to be set on the Barrel.

You may observe in the Tables, that from the end of each Table to the beginning, is the distance of two, or near two divisions: which is for a Pause, between the end of the Tune, and its beginning to Chime again.

I need not say, that the Dots running about the Tables, are the places of the Pins that play the Tune.

If you would have your Chimes compleat indeed, you ought to have a set of Bells, to the Gamut notes; so as that each Bell having the true sound of *Sol*, *La*, *Mi*, *Fa*, you may play any Tune, with its Flats and Sharps. Nay, you may by these means, play both the Bass and Treble, with one Barrel.

If any thing going before appears gibberish, I can't help it, unless I should here teach the skill of Music too.

As to setting a Tune upon the Chime-barrel from the number of Bells, *viz.* 1, 2, 3, 4, I shall here give you a specimen thereof.

*Such Commaud o're my Fate*, in numbers.

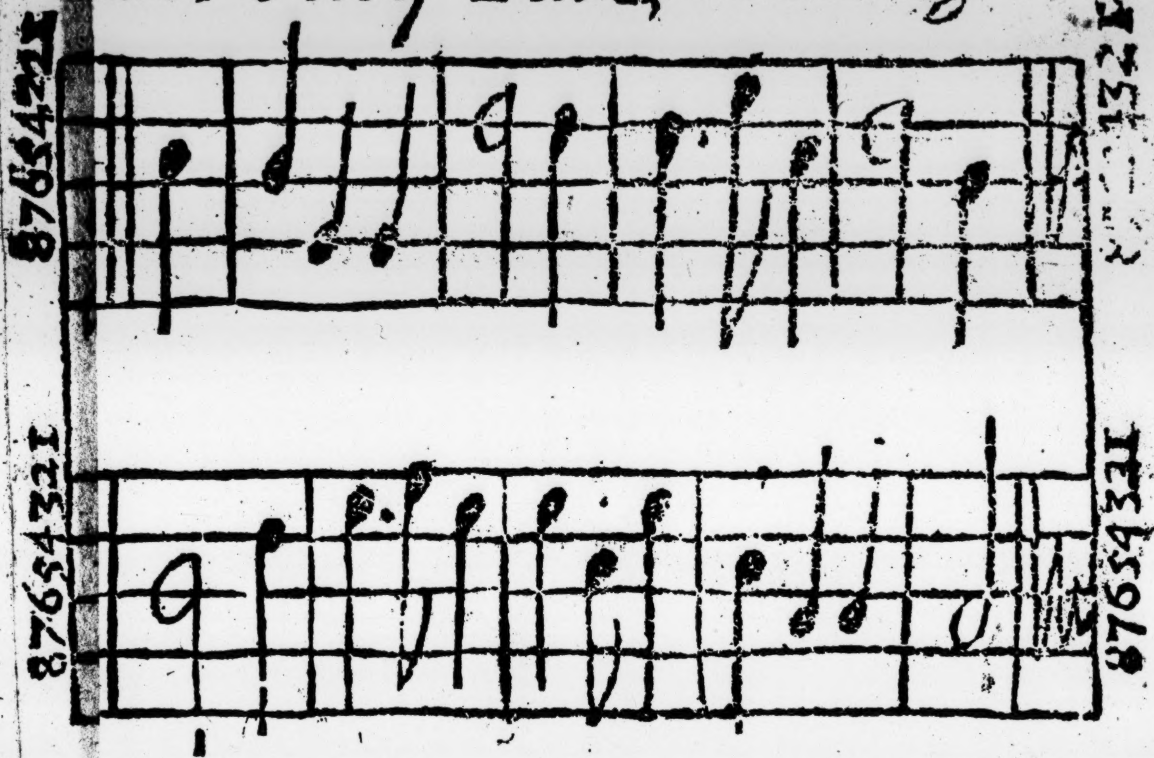
775. 3, 3, 1, 4, 5, 6, 4, 4, 2.
4, 3, 2, 3, 4, 6, 3, 5, 7, 7, 7. ||
5, 6, 8, 8, 4. 4, 4; 3, 5, 4.
6, 5, 7, 5, 3; 41, 3, 5, 5, 5.
3, 3, 1, 3, 5. 554, 2, 4, 6.
4, 3; 23, 3; 53, 5, 7, 7, 7.

*Note*, In these numbers, a Comma [,] signifies the note before it, to be a Crotchet. A prick'd Comma, or Semi-colon [;] denoteth a prick'd Crotchet. And a Period [.] is a Minum. Where no punctation is, those Notes are Quavers.

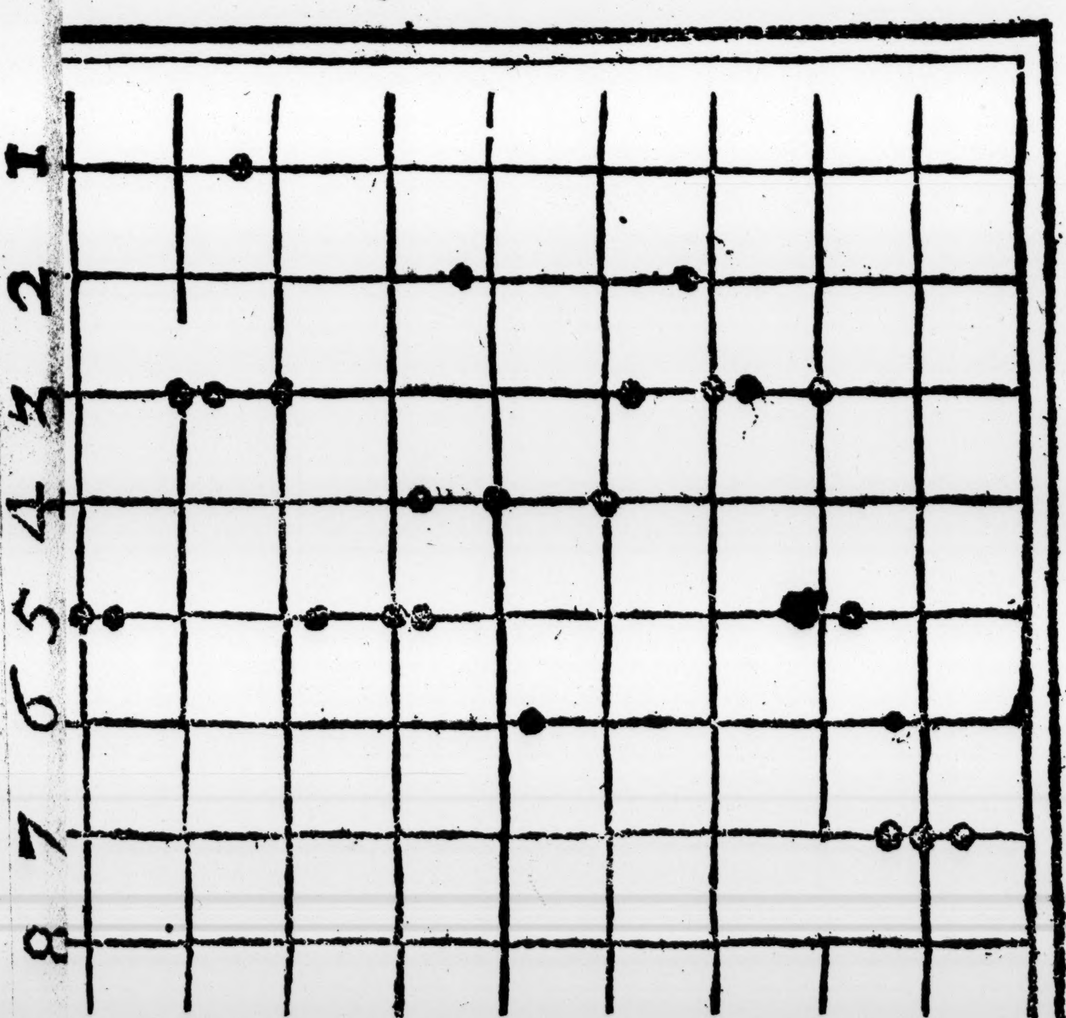
I shall only add further, that by setting the Names of your Bells at the head of any Tune (as is done in the Tables before) you may easily transfer that Tune, to your Chime-barrel, without any great skill in Musick. But observe, that each line in the Musick is three notes distant; *i. e.* there is a Note between each line, as well as upon it: as is manifest by inspecting the Tables.

SECT.

ndo're my Fate, &c A song

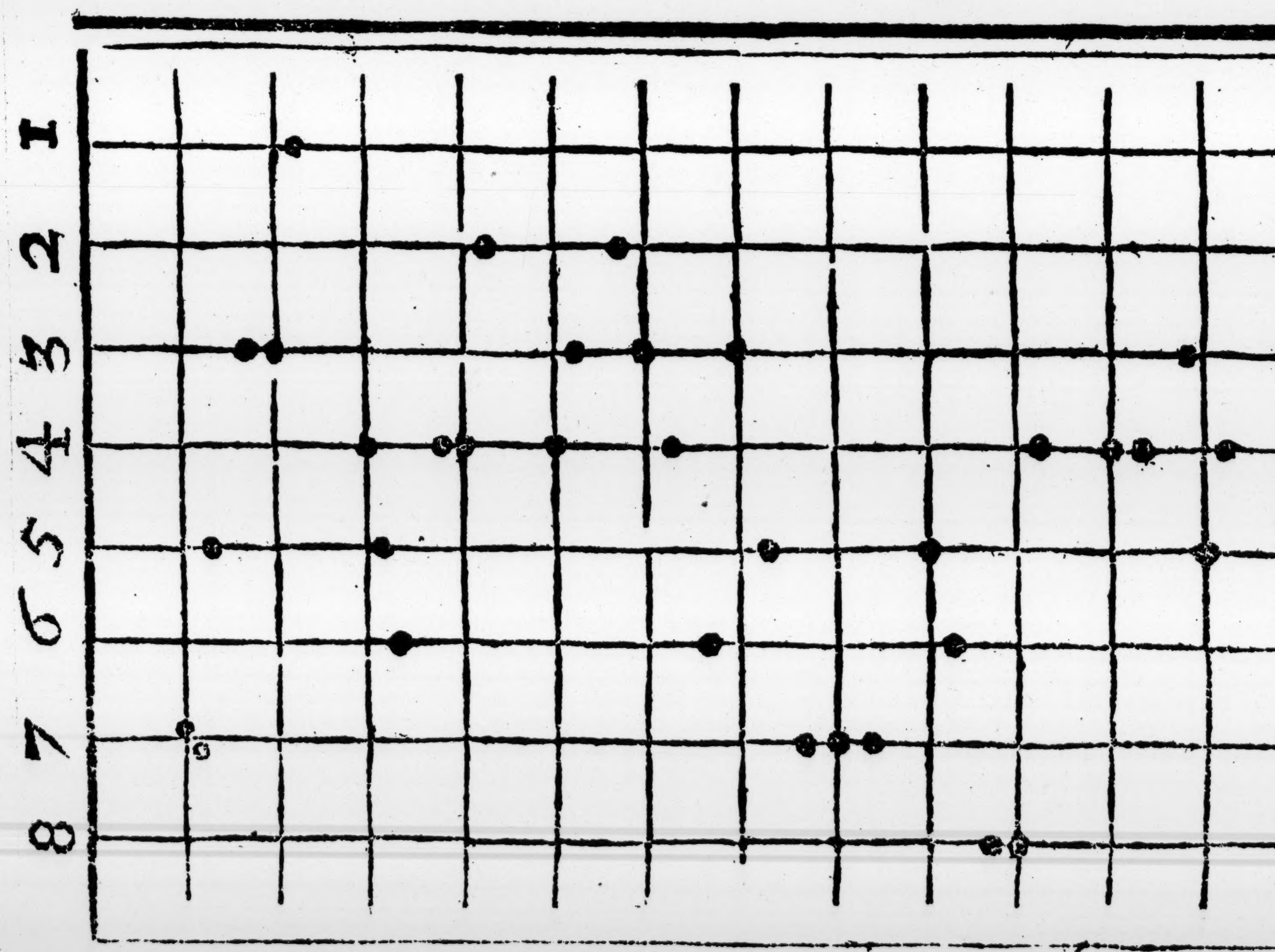



d o're my Fate, &c.

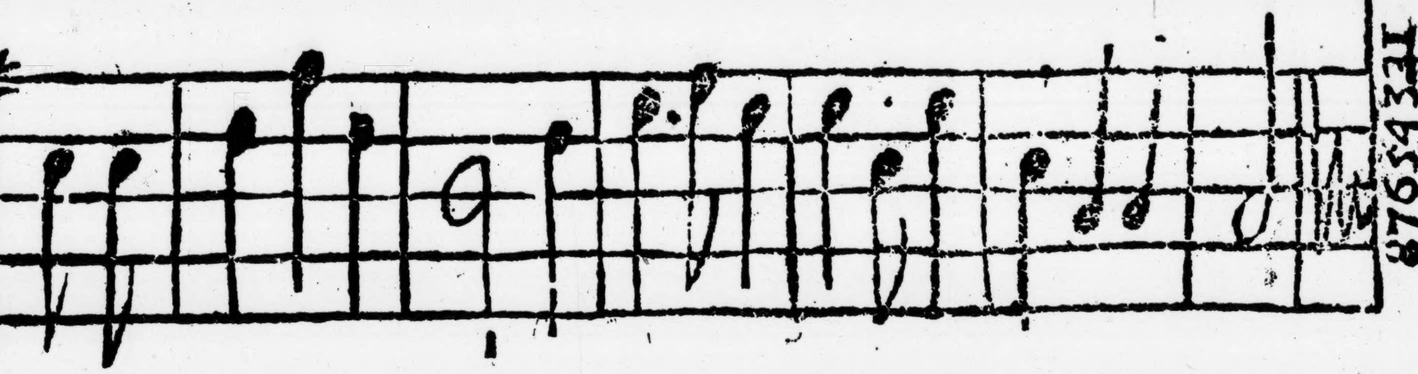


# The Musical Notes of, *Such*

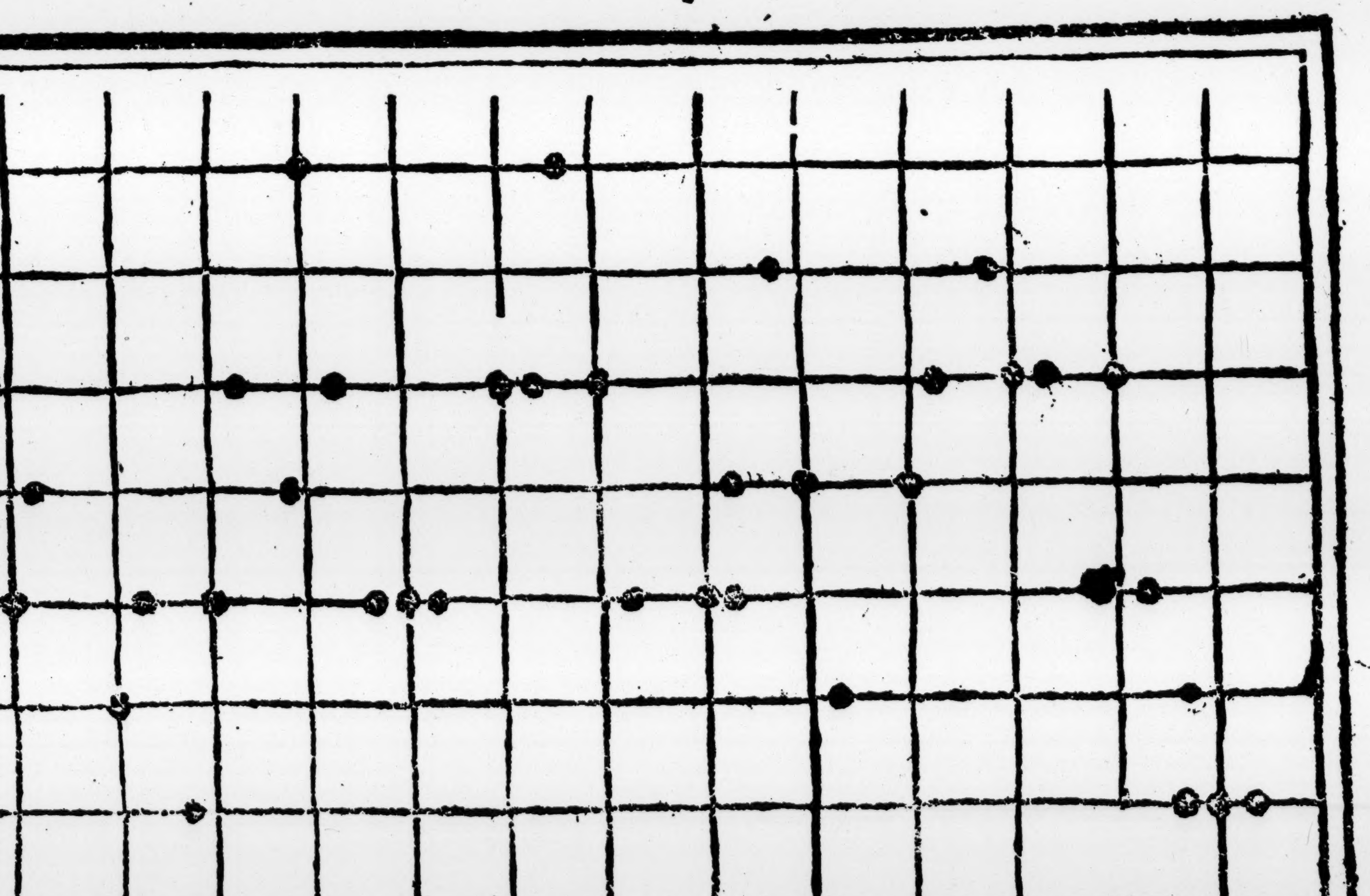

## The Chimes of the Song, *Such C*



uch Command o're my Fate, &c A song




h Command o're my Fate, &c.



## SECT. 5.

*To Calculate any of the Celestial Motions.*

The Motions I here chiefly intend, are the day of the Month, the Moons age, the day of the Year, the Tides, and (if you please) the slow motion of the Suns *Apogæum*, of the fixed Stars, the motion of the Planets, *&c.*

§ 1. For the effecting these motions in Watch work, you may make them to depend upon the Work already in the Movement; or else measure them by the beats of a Ballance or Pendulum.

If the latter way, you must however contrive a piece (as before in Watch-work) to go a certain time, with a certain number of turns.

But then to specificate, or determine the Motion intended, you must proceed one of these two ways: either,

1. Find how many beats are in the Revolution. Divide these beats by the beats in one turn of the Wheel, or Pinion, which you intend shall drive the intended Revolution; and the Quotient shall be the number to perform the same. Which, if too big for one, may be broken into more Quotients. Thus, if you would represent the Synodical Revolution of

the Moon, which is 29 days, 12 ¾ hours) with a Pendulum that ſwings Seconds, the Movement to go 8 days, with 16 turns of the Fuſy, and the Great-wheel to drive the Revolution, Divide 2551500 (the beats in 29 days 12 ¾ hours) by 43200 (the beats in one turn of the Great-wheel) and you will have 59 in the Quotient : which being too big for one, may be put into two Quotients. Or,

2. You may proceed as is directed before, in the Section of calculating Watch-work, *viz.* Chuſe your Train, turns of the Fuſy, Continuance, *&c.* And then inſtead of finding a Quotient for the Pinion of Report, find a number (which is all one as a Pin. of Report) to ſpecificate your Revolution, by this following Rule.

Ch. 2. Sect. 2. § 7.

*Rule.* As the Beats in one turn of the Great wheel : to the Train :: So are the Hours of the Revolution, to the Quotient of the Revolution.

Thus to perfom the Revolution of *Saturn* (which is 29 years, 183 days) with a 16 hour Watch, of 26928 Beats in one turn of the Fuſy, and 20196, the Train : the quotient of the Revolution will be 193824. For As 26928, To 20196 :: So 258432 ( the hours in 29 y. and 183 d. ) To 193824 Note here, that the Great-wheel pinion

nion is to drive the Revolution work.

But if you would have the Revolution to be driven by the Dial-wheel, and the work already in the movement (which in Great Revolutions, is for the most part, as nice as the last way, and in which I intend to treat of the particular Motions) in this case, I say, you must first know the Days of the Revolution. And because the Dial-wheel commonly goeth round twice in a day, therefore double the number of the days in the Revolution, and you have the number of turns of the Dial-wheel in that time. This number of turns is what you are to break into a convenient number of Quotients, for the Wheels and Pinions; as shall be shewed in the following examples.

§ 2. A Motion to shew the Day of the Month.

The days in the largest Month are *Oughtred*
31. These doubled are 62, which are §. 32.
the turns of the Dial-wheel, which may be broken into these two quotients 15 $\frac{1}{2}$ and 4; which multiplied together make 62. Therefore chusing your Wheels and Pinions, as hath been directed in the former Sections, your work is done. The Wheels and Pinions may be, as you see done in the Margin. Or if a larger Pinion than

4)62(15$\frac{1}{2}$
5)20(4

than one of 5 be necessary, by reason it is concentrick to a Wheel, you may take 10 for the Pinion, and 40 for the Wheel, as in the Margin.

4)62(15½
10)40(4

The work will lye thus in the Movement, *viz.* Fix your Pinion 10, concentrical to the Dial wheel (or to turn round with it upon the same Spindle.) This Pinion 10 drives the Wheel 40: which Wheel has the Pinion 4 in its center, which carrieth about a Ring of 62 teeth, divided on the upper side into 31 days.

Or, you may, without the trouble of many Wheels, effect this motion, *viz.* By a Ring divided into 30 or 31 days, and as many Fangs or Teeth, like a Crown wheel teeth, which are caught and pushed forward once in 24 hours by a pin in a Wheel, that goeth round in that time. This is the usual way in the Royal Pendulums, and many other Watches; and therefore being common, I shall say no more of it.

Id. ib. § 33.

*§ 3. A Motion to shew the age of the Moon.*

The Moon finisheth her course, so as to overtake the Sun in 29 days, and a little above an half. This 29 ½ days (not regarding the small excess) makes

59 twelve hours, or turns of the Dial-wheel, which is to be broken into convenient quotients: which may be 5.9 and 10, as in the first example; or 14 $\frac{3}{4}$ and 4, as in the second example in the Margin. So that if you fix a Pinion of 10 concentrical with your Dial wheel, to drive a Wheel of 40 (according to the last example) which Wheel 40 drives a pinion 4, which carries about a Ring, or Wheel of 59 teeth, once in 29 $\frac{1}{2}$ days. Which Ring may be divided into 29 $\frac{1}{2}$ parts; or carry an Index to point to a circle so divided.

| | |
|---|---|
| 10)59(5.9 | 4)59(14$\frac{3}{4}$ |
| 4)40(10 | 10)40(4 |

§ 4. *A Motion to shew the day of the Year, the Sun's place in the Ecliptick, Sun's Rising or Setting, or any other annual motion of 365 days.* Id. ib.

The double of 365 is 730, the turns of the Dial-wheel in an year: which may be broken into these quotients, *viz.* 18 $\frac{1}{4}$, and 10, and 4, according to the first example; or 18 $\frac{1}{4}$, 8, and 5, according to the second. So that a pinion of 5 is to lead a Wheel of 20; which again by a Pinion of 4, leadeth a wh. of 40; which 3dly by a Pin. of 4. carrieth about a Wh. or Ring of 73, divided

| | |
|---|---|
| 4)73(18$\frac{1}{4}$ | 4)73(18$\frac{1}{4}$ |
| 4)40(10 | 4)32(8 |
| 5)20(4 | 4)20(5 |

than one of 5 be necessary, by reason it is concentrick to a Wheel, you may take 10 for the Pinion, and 40 for the Wheel, as in the Margin.

4)62(15½
10)40(4

The work will lye thus in the Movement, *viz.* Fix your Pinion 10, concentrical to the Dial wheel (or to turn round with it upon the same Spindle.) This Pinion 10 drives the Wheel 40: which Wheel has the Pinion 4 in its center, which carrieth about a Ring of 62 teeth, divided on the upper side into 31 days.

Or, you may, without the trouble of many Wheels, effect this motion, *viz.* By a Ring divided into 30 or 31 days, and as many Fangs or Teeth, like a Crown wheel teeth, which are caught and pushed forward once in 24 hours by a pin in a Wheel, that goeth round in that time. This is the usual way in the Royal Pendulums, and many other Watches; and therefore being common, I shall say no more of it.

Id. ib. § 33.

*§ 3. A Motion to show the age of the Moon.*

The Moon finisheth her course, so as to overtake the Sun in 29 days, and a little above an half. This 29 ½ days (not regarding the small excess) makes

59 twelve hours, or turns of the Dial-wheel, which is to be broken into convenient quotients: which may be 5.9 and 10, as in the first example; or 14 ¾ and 4, as in the second example in the Margin.

| | |
|---|---|
| 10)59(5.9 | 4)59(14¾ |
| 4)40(10 | 10)40(4 |

So that if you fix a Pinion of 10 concentrical with your Dial wheel, to drive a Wheel of 40 (according to the last example) which Wheel 40 drives a pinion 4, which carries about a Ring, or Wheel of 59 teeth, once in 29 ½ days. Which Ring may be divided into 29 ½ parts; or carry an Index to point to a circle so divided.

§ 4. *A Motion to shew the day of the Year, the Sun's place in the Ecliptick, Sun's Rising or Setting, or any other annual motion of 365 days.* Id. ib.

The double of 365 is 730, the turns of the Dial-wheel in an year: which may be broken into these quotients, *viz.* 18 ¼, and 10, and 4, according to the first example; or 18 ¼, 8, and 5, according to the second.

| | |
|---|---|
| 4)73(18¼ | 4)73(18¼ |
| 4)40(10 | 4)32(8 |
| 5)20(4 | 4)20(5 |

So that a pinion of 5 is to lead a Wheel of 20; which again by a Pinion of 4, leadeth a wh. of 40; which 3dly by a Pin. of 4. carrieth about a Wh. or Ring of 73, divided

into the 12 months, and their days; or into the 12 signs, and their degrees; or into the Suns Rising and Setting, &c. For the setting on of which last, you have a Table in Mr *Oughtred*'s *Opuscula*.

Autom. § 35.

§ 5. *To shew the Tides at any Port.*

Id. ib. § 37.

This is done without any other trouble, than the Moons Ring (before mentioned § 3.) to move round by a fixed circle, divided into twice 12 hours, and numbered the contrary way to the age of the Moon.

To set this to go right, you must find out at what point of the Compass the Moon makes full Sea, at the place you would have your Watch serve to. Convert that point into hours, allowing for every point North or S. lost, 45 of an hour. Thus at *London-bridge* 'tis vulgarly thought to be high Tide, the Moon at N. E. and S. West, which are 4 points from the N. and S. Or you may do thus: by Tide Tables, learn how many hours from the Moon's Southing, 'tis High-water. Or thus; find at what hour it is High-water, at the Full, or Change of the Moon: as at *London-bridge*, the full Tide is commonly reckoned to be 3 hours from the Moons Southing; or at 3 of clock at the Full and Change. The day of Conjunction, or New-Moon, with a little stud to point, being set to the hour so found, will afterwards

wards point to the hour of full Tide.

This is the usual way; but it being always in motion, as the Tides are not, a better way may be found out, *viz.* by causing a Wheel, or Ring to be moved forward, only twice a day. and to keep time (as near as can be) with Mr. *Flamsteed*'s most correct Tables. But this I shall commit to the Readers contrivance, it being easie, and more of curiosity than use.

§ 6. *To Calculate Numbers, to shew the Motion of the Planets, the slow Motion of the fixed Stars, and of the Sun's Apogeum,* &c.

Having said enough before that may be applied here, and they being only curiosities, seldom put in practice, I shall not therefore trouble the Reader, or swell my Book with so many words, as would be required to treat of these Motions distinctly, and compleatly.

Only thus much in general. Knowing the years of any of these Revolutions, you may break this number into quotients; if you will make the Revolution to depend upon the years motion; which is already in the Movement, and described § 4. before. Or if you would have it depend upon the Dial-wheel, or upon the beats of a Pendulum, enough is said before to direct in this matter.

In all these slow motions, you may somewhat shorten your labour, by endless Screws to serve for Pinions, which are but as a Pinion of one tooth.

Mat.Com. p. 117. Sir *Jonas Moor*'s account of his large Sphere going by Clock-work, will sufficiently illustrate this paragraph. In this Sphere, is a Motion of 17100 years, for the Sun's *Apogeum*, performed by 6 Wheels, thus, as Sir *Jonas* relates it; "For the Great-wheel fixed is 96, a "Spindle-wheel of 12 bars turns round "it 8 times in 24 hours, that is, in 3 "hours; after these there are four "Wheels, 20, 73, 24, and 75, wrought "by endless Screws that are in value "but one: therefore 3, 20, 73, 24, and "75 multiplied together continually, "produceth 7884000 hours, which "divided by 24 gives 328500 days, "equal to 900 years. Now on the "last wheel 75 is a Pinion of 6, turning a great wheel, that carryeth the "*Apogeum* number 114: and 114 divided by 6, gives 19 the quotient: and "900 times 19 is 17100 years.

V. Sect. 1 § 4, 5.

Thus I have, with all the perspicuity I could, led my Reader through the whole Art of Calculation, so much of it at least, that I hope he will be master of it all; not only of those motions, which I have particularly treated about, but of any other not men-

mentioned: Such as the Revolution of the Dragons Head and Tail, whereby the Eclipses of the Sun and Moon are found, the Revolution of the several Orbs, according to the *Ptolemaick* System, or of the celestial bodies themselves, according to better Systems, with many other such curious performances, which have made the Sphere of *Archimedes* of old famous: and since him, that of *William* of *Zeland*, and another of *Janellus Turrianus* of *Cremona*, mentioned by *Cardan*: and of late, that elaborate piece of Mr *Watson*, late of *Coventry*, now of *London*, in her late Majesties Closet.

*De Subtil. l. 17.*

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## CHAP. III.

## *To alter Clock-work, or convert one Movement into another.*

THis Chapter I design for the use of such, as would convert old Ballance Clocks into Pendulums, or would make any old work serve for the tryal of new motions, or would apply it to any other such like use.

§ 1. To do this, you may draw a Scheme of your old work: and so you

will ſee what Quotients you have, and what you will want. To do all which, there are ſufficient inſtructions in the preceding Chapter. A few inſtances will make all plain.

§ 2. Let us chuſe for inſtance an old Ballance Watch to be turned into a Pendulum of 6 inches. The old work is, the Great-wheel 56, the Pinion 7; the next Wheel 54, the Pinion 6; the Crown-wheel 19, *&c.* The Scheme of this work is in the Margin. The Quotients and Crown-wheel and 2 Pallets multiplied together continually, produce 2736, which are the ſtrokes of the Ballance, in one turn of the Great-wheel, by Sect. I. § 4, 5 of the laſt Chapter. And by the Quotient of the Dial-wheel (which is 12) it appears, that the Great-wheel goeth round once in an hour. Or you may find the beats in an hour, by § 5. laſt cited. Having thus found the Beats in an hour, of the old work, you muſt next find the Beats in an hour of a 6 inches Pendulum; which you may do by Chap. 5. § 4. following; or by Mr. *Smith*'s Tables, according to whom the number is, 9368. Divide this by 2736, and you have the Quotient, which

4)48(12
———
7)56(8
6)54(9
———
19

*Horol. Dis.* p. 54.

2736)9368(3 ½ which is to be added to the Scheme of the old work. This quotient is 3 and near ½, as you see in the Margin.

The work thus altered, will stand as you see in the Margin, *viz.* a Pinion 6, and a contrate-wheel 21, must be added.

4)48(12
———
7)56(8
6)54(9
6)21(3½
——
19

According to this way, the old work will stand as before, only the Crown-wheel must be inverted.

§ 3. But because the Crown-wheel is too big for the Contrate-wheel (which is unseemly) there fore it will be best to make both the Contrate and Crown-wheels new; and increase the number of the Contrate-wheel, but diminish that of the Crown-wheel. To do which, pitch upon some convenient number for the Crown-wheel. Multiply all the Quotients, and this new Crown-wheel number, as before; and divide 9368 by it. As suppose you pitch upon 11 for the Crown-wheel: if you multiply 8, 9 and 11, the product is 792; which multiplied by the 2 Pallets, makes 1584, which are the Beats in one turn of the Great-wheel, or in an hour. Divide 9368 by it, and you have

V. Sect. 1. § 6.

4)48(12
7)56(8
6(54(9
6)36(6
—
11

have near 6 for the Quotient of your Contrate-wheel. The work thus ordered, will ſtand as in the Margin.

If you would correct your work, to find the true number of Beats in an hour, *&c.* you muſt proceed, as is ſhewn Sect 2. § 6, and latter end of § 7. of the laſt Chapter.

§ 4 But ſuppoſe you have a mind to change the former old Watch, into a 30 hour piece, and to retain the old Ballance-wheel (which may be often done: in this caſe, you muſt add a Contrate-wheel, and alter the Pinion of report. For the Contrate-wheel, chuſe ſuch a Quotient as will beſt ſuit with the reſt of your work; and then multiply all your Quotients, Crown-wheel and 2 Pallets together, and ſo find the number of turns in the Great-wheel, as before. Then ſay by Sect. 2. § 6. part 5. before, as the Beats in one turn of the Great-wheel, to the beats in an hour:: So are the hours of the Dial, to the Quotient of the Pinion of Report.

Thus in the old work before; to the old Quotients 8, and 9, you may add another of 8, for the Contrate-wheel. Thoſe multiplied, as was now directed, make 21888, for the Beats in one turn of

of the Great-wheel. And then for the quotient of the Pinion of Report, say in numbers thus, 21888. 9368 : : 12. 5. The quotient for the Pinion of Report is somewhat more than 5, which overplus may be neglected, as you see by the Scheme of the whole work in the Margin.

6)30(5
7)56(8
6)54(9
6)48(8
——
19

If you desire to know what number of turns, the Fusy must have in this work; say by the last quoted §, part 1, in numbers thus, 21888. 9368 : : 30. 13 almost. So that near 13 turns will do.

If you would correct your work, to know the exact Beats, *&c.* you are referred to directions in the end of the last paragraph.

But suppose in altering an old Watch, you would have it shew minutes, as well as hours; you may do it thus: Divide the Beats in one turn of the Great-wheel, by the Beats in an hour; the Quotient will shew in how many hours the Great-wheel goeth round once. If the Beats in the Great-wheel exceed the Train, you must chuse your Minute-wheel first, and multiply it by the Quotient found; this will give the Pin. of Report. But if the Train exceeds the Beats of the Great-wheel, you must chuse the Pin. of Report and multiply the Quotient by it: the product is the Minute-wheel. But

But it often falls out, that the Train and Beats of the Great-wheel will not exactly measure one another: if so, the best way is to half the two numbers as far as they will equally admit of halfing; or divide them by some common divisor, and so having brought them to as small numbers as you can, you may suppose them to be a Wheel and Pinion, and reduce them to lesser numbers, by Chap. 2. Sect 2. § 5. Thus suppose you would make the old Movement last mentioned, a Minute-watch; you may reduce the numbers of the Great-wheel 21888, and the Train 9368, to a Pinion and Wheel 28) 12. by the directions in Chap. 2. Sect. 2. § 5. Which Pin. 28 being set upon the Spindle of the Gr. Wh. will drive a Wheel 12 round once in an hour, to shew Minutes. If (as in the Movements in Ch. 10) you make this Wh. 12 drive another of 48; concentrical to which, is a Pin. 12 driving a Wheel 36 (which Wheel is concentrical with the Minute wheel) this will carry a Hand round in 12 hours. But in this case, you must place the Pin. 28 on the Spindle of the Gr. Wh so as to slide round stiffly, when you turn the Minute hand to rectifie the Watch.

§ 5. I ſhall add but one thing more, to what hath been ſaid in this Chapter, and that is to change the ſtriking part of this old Movement, into a 30 hour, piece.

4)39(9¼  
7)56(8 pins  
6)54(9  
6)48(8

A Scheme of the old work is in the Margin.

And to alter it, the beſt way is, to double the number of ſtriking pins, making the 8, ſixteen pins: and the Hoop of the Detent wheel double, that the Pin-wheel may ſtrike two ſtrokes, in its going round once.

The greateſt inconvenience here, will be to bridle the rapidity of the ſtrokes; becauſe a quotient of (2 only, added to the old work, will be ſufficient for this purpoſe: which being an inconvenient number, 'twill be neceſſary to be content with the old numbers, or make more Wheels and Pinions new, than may be thought worth the while.

If you would find what number of turns, the Fuſy will require; you muſt find how many ſtrokes are in 30 hours, by Sect 3. § 2. R 6. before. Theſe are 195; which divided by the 16 Pins, gives ſomewhat more than 12 turns of the Fuſy.

Laſtly, for the Pinion of Report, you muſt purſue the directions in the laſt quoted place, R. 5.

The

5)24($\frac{78}{16}$
7)56)8.16 pins
6)54(9
6)48(8

The work thus altered, will ſtand as in the Margin.

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# CHAP. IV.

## *To ſize the Wheels and Pinions, or proportion them to each other, both Arithmetically and Mechanically.*

§ 1. FOr the exact and eaſie moving of the Wheels and Pinions together, it is neceſſary that they ſhould fit each other, by having their teeth and leaves of the ſame wideneſs, or near of the ſame wideneſs. For many do make the Leaves of the Pinion narrower than the teeth of its Wheel, by reaſon of their running deep in each other; which is as if the Diameters of the Wheel and Pinion were leſs. But this I leave to thoſe whoſe practice and obſervations are greater than mine in theſe matters.

§ 2. To make the Teeth of a Wheel and Pinion alike, the way *Arithmetically* is thus, Firſt you muſt find the Circumference of your Wheel and Pinion; which you may beſt do by the Rule of Three (ſo often made uſe of before) the

the Rule is thus, as 7 is to 22 :: ſo is the Diameter to the Circumference. Or more exactly thus, as 1, is to 3, 1416 : : So Diam. to Circum.

Suppoſe you have a Wheel of 2 inches diameter, and 60 Teeth, and would fit to it a Pinion of 6 Leaves. Firſt 7. 22 :: 2. 6,3. The circumference of the Wheel, is then 6 inches, and 3 tenths of an inch. Then ſay, as the Teeth of the Wheel to the circumference of it : : So are the Leaves of the Pinion, to the circumference thereof. In numbers thus 60. 6,3 :: 6. ,63. The Pinion then is 63 hundredth parts of an inch round. Sir *J. Moer* Mat. Com. R. 5

Now to find the Diameter, 'tis but the reverſe of the former Rule, *viz.* As 22. to 7 : : So the Circumference to the Diameter. In numbers thus, for the foregoing Pinion, 22. 7 : : 63. 2. The Diameter then of the Pinion muſt be two tenths of an inch, to fit the aforeſaid Wheel of two inches Diameter.

§ 3. But becauſe this way may be difficult to perſons unacquainted with Decimal Arithmetick, which is very neceſſary here ; therefore I ſhall ſet down a way to do it *Mechanically*. Having drawn a Circle, divide into as many parts as you intend Leaves in the Pinion you would ſize. From two of

theſe

these points in the Circle, draw two lines to the Center: to which apply two of the Teeth of your wheel, guiding them up and down until they touch at the same width on these Radii. Mark where this agreement is, and a small circle drawn there, will represent the circumference of the Pinion sought after.

## CHAP. V.

### Of Pendulums.

§ 1. AMong all known Motions, none measureth Time so regularly, as that of a Pendulum. But yet Watches govern'd hereby are not so perfect, but that they are subject to the variations of weather, foulness, &c. And the shorter and lesser the Pendulum is, so much the more subject such Watches are to these annoyances.

There are two ways to obviate these inconveniences in some measure. One way, is, to make the Pendulum long, the Bob heavy, and to vibrate but a little way from its settlement. Which is now the most usual way in *England* The other is the contrivance of the ingenious Mr. *Hugens*, which is, to make the upper

per part of the rod, play between two cheek parts of the Cycloid. Sir *Jonas Moor* ſays, that after ſome time, and charge of Experiments, he believes this latter to be the better way. And Mr. *Hugens* calls it *admirable*. Id. ib. Rule 3.

If any deſire to know how to make thoſe Cycloidal Cheeks fit to all Pendulums, I refer him to the aforeſaid Mr. *Zulichem*'s Book, becauſe I can't ſhew how to do it, without the trouble of Figures; and this way is much ceaſed, ſince the Crown-wheel method (to which it is chiefly proper) is ſwallowed up by the Royal Pendulums. *De Horol. Oſcil.* p. 10, 11, 12.

§ 2. Another thing to be remarked in Pendulums is, that the greater the Vibration is, the ſlower it is. For if two iſochrone Pendulums do move, one the quadrant of a circle, the other not above 3 or 4 degrees, this latter ſhall move ſomewhat quicker than the former. Which is the true reaſon, why ſmall Crown wheel Pendulums go faſter in cold weather, or when foul, than at other times. Yea, in the beſt Royal Pendulum, if you put a divided plate behind the Ball, and obſerve its ſwings, you may perceive the vibrations to be ſometimes ſhorter; and that then the Watch doth gain too much. Somewhat alſo may perhaps be attributed

ted to the rarity or denſity of the air; which I have not yet had an opportunity of obſerving, by comparing with a good Baroſcope, the various vibrations of a good Royal Pendulum. But Mr. *Boyl* ſays, that a Pendulum moveth as long, and as faſt in a thick medium, as a thin one, contrary to the opinion of ſome Naturaliſts, who think the contrary. His opinion is grounded upon the experiment of a Pendulum vibrating in his air-pump, the air ſucked out, and in the open air; wherein was no alteration.

*Machina Pneumat. Exp.* 26.

§ 3. For the calculation of all Pendulums, 'tis neceſſary to fix upon ſome one, to be as a Standard to the reſt. I pitch upon a Pend. to vibrate ſeconds each ſtroke.

Mr. *Hugens* lays down the length of a Pend. to ſwing ſeconds to be 3 feet, 3 inches, and 2 tenths of an inch (according to Sir *J. Moor*'s reduction of it to *English* meaſure.)

Ibid.

" The Honourable Lord *Bruncker* (ſaith Sir *Jonas*) " and Mr. *Rook*, " found the length to be 39. 25 inches, " which a little exceeds the other: " and may be, was juſtened by Mr. *Hugens* Rule for the Center of Oſcilla- " tion. For *Mounton*'s Pendulum, that " ſhall vibrate 132 times in a minute, " it will be found likewiſe 8. 1 inches, " agree-

Ibid.

"agreeing to 39.2 inches *Engliſh.* There-
" fore for certain 39.2 inches may be
" called the *Univerſal meaſure*, and reli-
" ed on, to be the near length of a
" Pend. that ſhall ſwing ſeconds each
" vibration.

But foraſmuch as the different ſize of the Ball, will make ſome difference in the length of this Standard Pendulum, therefore to make this Pend. an *Univerſal meaſure*, to fit all places and Ages, you muſt meaſure from the point of Suſpenſion, to the Center of Oſcillation. Which Center is found by this Rule, as the length of the String from the point of Suſpenſion to the Center of a round Ball : is to the Semi-diameter of that Ball :: So is that Semi-diameter to a 4th number. Add two 5ths of that 4th number, to the former length and you have the Center of Oſcillation ; and thereby the true length of this *Standard Pendulum*.

*Hugenius ubi ſupra* p. 141. Sir *J. Moor* ibid.

If it be deſired to fit a Ball of a triangular, quadrangular, or any other form to this Pend. the Center of Oſcillation in any of theſe bodies may be found in the laſt cited Book of Mr. *Zulichem*.

If it be asked, what is the meaning of the Center of Oſcillation? the moſt intelligible anſwer is, that it is that point of the Ball, at which if you imagine it divided into two parts, by a circle,

circle, whose center is in the point of Suspension, the lower part of the Ball shall be of the same weight (or near so) with the upper.

§ 4. Having thus fixed a Standard, I shall next shew how from thence to find the Vibrations, or Lengths of all other Pendulums. Which is done by this Rule, *The squares of the Vibrations, bear the same Proportion to each other, as their Lengths do.* And so contrarywise. Wherefore to find the length of a Pend. say, as the Square of the Vibrations given: to the Square of 60 (the Standard) :: So is the length of the Standard (*viz.* 39,2) to the length of the Pend. sought.

Hugen Moor ib.

If by the length, you will find the Vibrations 'tis the Reverse of the last Rule, *viz.* as the length proposed: to the Standard (39,2) :: So is the Square of 60 (the vibrations of the Standard): to the square of the Vibrations sought.

Suppose for example, you would know what length a Pend. is that vibrates 153 strokes in a minute. The square of 153 (*i. e.* 153 times 153) is 23409. Say 23409. 3600 :: 392. 6. A Pend then that vibrates 153 in a minute, is about 6 inches long.

On the other hand, if you would know how many strokes a Pend of 6 inches hath in a minute; say, 6. 39,2:: 3600. 23520. The square root whereof is 153, and somewhat more. *Note,*

*Note*, becauſe 141120 is always the product of the two middle terms multiplied together, therefore you need only to divide this number by the ſquare of the Vibrations, it gives the length ſought: by the length, it gives the ſquare of the Vibrations.

If you operate by the Logarithms, you will much contract your labour. For if you ſeek the length, 'tis but ſubſtracting the Logarithm of the Square of the Vibrations, out of the Logarithm of 141120, which is 5. 149588, and the Remainder is the Logarithm of the length ſought.

If you ſeek the Vibrations, it is but Subſtracting out of the aforeſaid Logarithm 5. 149588, the Logarithms of the length given, and half the Reſidue is the Logarithm of the Vibrations required. The following examples will illuſtrate each particular.

### To find the Length.

| | Logarithms. |
|---|---|
| 141120 ———————— | 5. 149588 |
| 153 Squared is 23409 ——— | 4. 369382 |
| Length is more than 6. —— | 0. 780206 |

To

To find the Vibrations.

| | Logarithms. |
|---|---|
| 141120 | 5. 149588 |
| 6 inches long | 0. 778151 |
| Square of the Vibr. | 4. 371437 |
| Square root, or numb. of Vibr. | 2. 185718 |

is 153, and ſomewhat more.

According to the foregoing Directions, I have calculated the following Table, to Pendulums of various lengths, and have therein ſhewed the Vibrations in a minute and an hour, from 1 to a 100 inches. If any deſire a more minute account, I refer him to Mr *Smith*'s Tables in his late Book. The reaſon why his calculation and mine differ, is becauſe he meaſureth the length of the Pend. from the point of Suſpenſion, to the lower part of the Bob; and I only to the center of the Bob. His Standards are 6 $\frac{1}{2}$ inches, and 41 inches; and mine is 39,2, for the reaſons aforegoing.

*Horolog. Diſquiſ.*

*A Table of Swings in a Minute, and in an hour, to Pendulums of ſeveral lengths.*

| Pend. length in inches | Vibrat. in a Minute | Vibrat. in an Hour. | Pend. length in inches | Vibrat. in a Minute | Vibrat. in an Hour. |
|---|---|---|---|---|---|
| 1 | 375.7 | 22542 | 30 | 68.6 | 4116 |
| 2 | 265.6 | 15936 | | | |
| 3 | 216.9 | 13014 | 39.2 | 60.0 | 3600 |
| 4 | 187.8 | 11268 | | | |
| 5 | 168.0 | 10080 | 40 | 59.4 | 3564 |
| 6 | 153.3 | 9204 | 50 | 53.1 | 3186 |
| 7 | 142.0 | 8520 | 60 | 48.5 | 2910 |
| 8 | 132.8 | 7968 | 70 | 44.9 | 2694 |
| 9 | 125.2 | 7512 | 80 | 42.0 | 2520 |
| 10 | 118.8 | 7128 | 90 | 39.6 | 2376 |
| 20 | 84.0 | 5040 | 100 | 37.5 | 2250 |

The uſe of this Table is manifeſt, and needs no explication. As to the Decimals in the column of Minute-Swings, I have added them for the ſake of calculating the column of Hour-Swings; which would have been judged falſe without them, and would not have been exactly true without them.

§ 5. I have but one thing more to add to this Chap. of Pendulums, and that is, *To Correct their Motion.*

The uſual way is, to ſcrew up, or let down the Ball. In doing of which, a

small alteration will make a considerable variation of time: as you will find by calculation, according to the last paragraph. To prevent the inconvenience of screwing the Ball too high, or low, Mr. *Smith* hath contrived a very pretty Table for dividing the Nut of a Pendulum Screw, so as to alter your Clock but a second in a day. But by reason no Screw and Nut can be so made, as to be most exactly strait and true, therefore it may happen, that instead of altering your Watch to your mind, you may do quite contrary; as instead of letting the Ball down, you may raise it higher, by the false running of the Nut upon the Screw.

Ibid.

Considering this irremediable inconvenience, I am of opinion, that Mr. *Hugens*'s way would do very well, added to this. His way is, to have a small Weight or Bob, to slide up and down the Pend. rod, above the Ball (which is immoveable.) But I would rather advise, that the Ball be made to screw up and down, to bring the Pend. pretty near its gauge: and that this little Bob should serve only for more nice corrections; as the alteration of a second, or *&c.* Which it will do better than the Great Ball For a whole turn of this little Bob, will not affect the

Ibid. *de Centro Oscil.* Prop. 23.

the motion of the Pend. near ſo much as a ſmall alteration of the Great Ball.

The Directions Mr. *Hugens* gives, about this little Corrector, is, that it ſhould be equal to the weight of the Wire, or Rod of the Pend. or about a 50th part of the weight of the Great Ball, which he appoints to be three pounds.

Perhaps this Bob may do its office, if it be made to ſcrew only up and down the lower part of the Rod, below the Ball. If not, you muſt make it ſlide above the Ball, or be ſcrewed up and down there.

Seeing this little Bob is not the only Corrector (as in Mr. *Zulichem*'s way) therefore it is not neceſſary to inſert here, that ingenious perſon's Table, ſhewing what alterations of time will be made by ſliding the Bob up and down the rod. Only thus much may be obſerved in that Table of his, *viz.* that a ſmall alteration of the Corrector towards the lower end of the Pend. doth make as great an alteration of time, as a greater raiſing or falling of it, doth make higher. Thus the little Bob raiſed 7 diviſions of the Rod, from the Center of Oſcillation, will alter the Watch 15 ſeconds; raiſed 15.2 'twill alter it 30". But whereas,

if it be raiſed to 154.3 parts of the Rod, it will make the Watch go faſter 3 minutes, 15 ſeconds, the Watch ſhall be but 3′. 30″ faſter, if the Bob be raiſed to 192.6. So that here you have but 15″ variation, by raiſing the Bob above 38 parts; whereas lower, you had the ſame variation, when raiſed not above 7 or 8 parts.

From what hath been ſaid it appears, that about half a turn of this little juſtening Bob, will at no time alter the Watch, above a ſecond in 24 hours: and that above a whole turn, will not alter it ſo much, higher on the Rod; ſuppoſing that the Bob at every turn aſcended or deſcended a whole degree of the Rod; which perhaps it will not do in 20 turns: and conſequently, it will require many turns, to alter the Watch but one ſecond.

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## CHAP. VI.

### *The Antiquity, and general Hiſtory of Watch, or Clock-work.*

§ 1. IT is probable, that in all Ages, ſome Inſtruments or other have been uſed, for the meaſuring of time. But the earlieſt we read of, is the *Dial* of

of *Ahaz*. Concerning which, little of certainty can be ſaid. The *Hebrew* word *Mayaloth* doth properly ſignifie Degrees, Steps, or Stairs, by which we aſcend to any place. And ſo this word *Mayaloth* is rendered *Ezek.* 40. 26. And accordingly the LXXII tranſlate the M*ayaloth* of *Ahaz*, by the words Βαθμοὺς and Ἀναβαθμοὺς i. e. *Steps* or *Aſcents*. The like doth the *Syriack*, *Arabick*, and other Verſions. *2 Kings. 20. 11. Iſai. 38. 8.*

Some pretend to give a deſcription of this *Dial* of *Ahaz*: but it being meer gueſſing, and little to my purpoſe, I ſhall not trouble the Reader with the various opinions about it.

Among the *Greeks* and *Romans*, there were two ways chiefly uſed to meaſure their hours. One was by *Clepſydræ*, or Hour-glaſſes. The other by the *Solaria* or Sun-dials. The Κλεψύδρα, ſay *Suidas* and *Phavorinus*, was Ὄργανον ἀστρολογικὸν ἐν ᾧ αἱ ὧραι μετροῦνται: *i. e. An Aſtronomical Inſtrument, by which the hours were meaſured.* Alſo, *that it was a Veſſel, having a little hole in the bottom, which was ſet in the Courts of Judicature, full of water; by which the Lawyers pleaded.* This was, ſays *Phavorinus*, to prevent babbling, that ſuch as ſpake, ought to be brief in their Speeches. *Lexic. in verbo. ὧραι.* *In verbo κλεψύδρα*

As to the Invention of thoſe Water-watches (which were, no doubt, of

more common use, than only in the Law-Courts) the Invention, I say of them, is attributed, by *Censorinus*, to *P. Cornelius Nasica*, the *Censor* (*Scipio Nasica*, *Pliny* calls him.)

*De die Natali* c. 23.

The other way of measuring the hours with *Sun dials*, seems, from *Pliny* and *Censorinus*, to have been an earlier invention than the last. *Pliny* says, that *Anaximenes Milesius*, the Scholar of "*Anaximander*, invented Dialling, and "was the first that shewed a Sun-dial "at *Lacedæmon*. *Vitruvius* calls him *Milesius Anaximander*. This *Anaximander* or *Anaximenes* was cotemporary with *Pythagoras*, says *Laertius*; and flourished about the time of the Prophet *Daniel*.

Ibid.

*Nat. Hist.* l. 2. c. 76.

*De Archit* l. 6. c. 48.

But enough of these ancient Time-engines, which are not very much to my purpose, being not pieces of Watch-work.

§ 2. I shall in the next place take notice of a few Horological Machines, that I have met with; which, whether pieces of Clock work, or not, I leave to the Reader's judgment.

The first is that of *Dionysius*, which *Plutarch* commends for a very magnificent, and illustrious piece. But this might be only a well delineated Sun-dial.

In the Life of *Dion.*

Another Piece, is that of *Sapor* King of *Persia*. Whether that *Sapor*, who was

*Euseb. Vit. Const.* l. 3.

was cotemporary with *Constantine the Great*, I know not. *Cardan* saith it was made of Glass; that the King could sit in the middle of it, and see its Stars rise and set. But not finding whether this Sphere was moved by Clock-work, or whether it had any regular motion, I shall say no more concerning it. *De Subtil, l. 17.*

The last Machine I shall mention in this Paragraph, is one I find described by *Vitruvius*. Which to me seems to be a piece of Watch-work, moved by an equal influx of Water. *De Archi. tect. l. 9. c. 9*

If the Reader will cousult the *French* Edition of *Vitruvius*, he will find there a fair cut of it.

Among divers feats which this Machine performed (as sounding Trumpets, throwing Stones, *&c.*) one use of it was, to shew the hours (which were unequal in that age) through every month of the year. The words of *Vitruvius* are, *Æqualiter influens aqua sublevat Scaphum inversum (quod ab artificibus Phellos sive Tympanum dicitur) in quo collocata regula, versatilia tympana denticulis æqualibus sunt perfecta. Qui denticuli alius alium impellentes, versationes modicas faciunt, ac motiones. Item aliæ Regulæ, aliaque Tympana ad eundem modum dentata, quæ una motione coacta, versando faciunt effectus, varietatesque motionum: in quibus moventer Sigilla, vertuntur Metæ,*

*Calculi aut Tona projiciuntur, Buccinæ canunt, &c. In his etiam, aut in columna, aut parastatica Horæ describuntur; quas Sigillum egrediens ab imo virgulæ, significat, in diem totum: quarum brevitates aut crescentias, caneorum adjectus aut exemptus, in singulis diebus & mensibus, perficere cogit.*

The Inventer of this famous Machine, *Vitruvius* says, was one *Ctesibius*, a Barbers Son of *Alexandria*. Which *Ctesibius* flourisht under *Ptolomy Euergetes*, says *Athenæus*, l. 4. And if so, he lived about 240 years before our Saviours days; and might be cotemporary with *Archimedes*.

Vid. *Philand. not. in Vitruv.*

§ 3. Thus having given a small account of the ancient ways of measuring time, it is time to come closer to our business, and say something more particularly of Watch and Clock-work. Which is thought to be a much younger invention, than the fore mentioned Pieces; and to have had its beginning in *Germany*, within less than these 200 years. It is very probable, that our Ballance-clocks or Watches, and some other *Automata*, might have their beginning there; or that Watch and Clock-work (which had long been buried in oblivion) might be revived there. But that Watch and Clock-work was the invention of that age purely, I utterly deny; having (besides what goes before) two instances to the contrary, of much earlier date.

§ 4.

§ 4. The first example is the *Sphere* of *Archimedes*; who lived about 200 years before our Saviours days. There is no mention of this Sphere in *Archimedes* his extant works: but we have an account of it in others. *Cicero* speaks of it more than once. In his 2d Book *De Natura Deorum*, are these words; "*Archimedem aribtrantur plus valuisse in* "*imitandis Sphæræ conversionibus, quam* "*Naturam in efficiendis*, &c. And in his *Tusculane* Questions, the Collocutor, proving the Soul to be of a divine Nature, argues from this contrivance of *Archimedes*, and says, *Nam cum Archimedes Lunæ, Solis, quinque errantium motus in Sphæram illigavit, effecit, &c.* The sense is, that *Archimedes* contrived a Sphere, which shewed the motion of the Moon, Sun, and five Planets. Lib. 1. §. 25. *Edit. Elzevir.*

But the most accurate description is that of *Claudian*, in these words. *Epigr. in Sphær. Archimed.* Vid. *Card. de Subtil.* l. 17.

*Jupiter in parvo cum cerneret æthera vitro,*
*Risit, & ad Superos talia dicta dedit:*
*Huccine mortalis progressa potentia curæ?*
*Jam meus in fragili luditur orbe labor.*
*Jura poli, rerumque fidem, legesq; Deorum*
*Ecce Syracusius transtulit arte Senex.*
*Inclusus variis famulatur Spiritus astris,*
*Et vivum certis motibus urget opus.*
*Percurrit proprium mentitus Signifer annum.*
*Et simulata novo Cynthia mense redit.*

*Jamq; suum volvens audax industria mundum*
*Gaudet, & humana Sidera mente regit.*
*Quid falso insontem tonitru Salmonea miror?*
*Æmula Naturæ parva reperta manus.*

In *English* thus:

*When* Jove *espy'd in Glass his Heavens made,*
*He smil'd, and to the other Gods thus said:*
*Strange feats! when human art so far proceeds,*
*To ape in brittle Orbs my greatest deeds.*
*The heavenly motions, Natures constant course,*
*Lo! here old* Archimede *to art transfers.*
*Th' inclosed Spirit here each Star doth drive;*
*And to the living work sure motions give.*
*The Sun in counterfeit his year doth run,*
*And* Cynthia *too her monthly circle turn.*
*Since now bold man hath Worlds of's own descryd.*
*He joys, and th' Stars by human art can guide.*
*Why should we so admire proud* Salmons *cheats*
*When one poor hand Natures chief work repeats?*

From this description it appeareth, that in this Sphere, the Sun, Moon, and other heavenly bodies, had their proper motion: and that this motion was effected by some enclosed *Spirit*. What this *enclosed Spirit* was, I cannot tell, but suppose it to be Springs, Wheels or Pullies, or some such means of Clock work: Which being hidden from vulgar eyes, might be taken for some Angel, Spirit, or Divine power;

unless

unleſs by Spirit here, you underſtand ſome aerious, ſubtiliz'd liquor; or vapours. But how this, or indeed any thing but Clock-work, could give ſuch true and regular motions, I am not able to gueſs.

§ 5. The next inſtance I have met with of ancient Clock-work, is that famous one in *Cicero*, which, among other irrefragable arguments is brought in to prove, "That there is ſome intelligent, divine, and wiſe Being, "that inhabiteth, ruleth in, and is as "an Architect of ſo great a work, as "the World is, as the Collocutor expreſſeth himſelf. His words (ſo far as they relate to my preſent purpoſe) are theſe: "*Cum Solarium vel deſcriptum, aut* "*ex Aqua contemplere, intelligere declarari* "*horas arte, non caſu,* &c. And a little after, *Quod ſi in Scythiam, aut in Britanniam, Sphæram aliquis tulerit hanc, quam nuper familiaris noſter effecit Poſidonius, cujus ſingulæ Converſiones idem efficiunt in Sole, & in Luna, & in quinque Stellis errantibus quod efficitur in cælo ſingulis diebus, & noctibus; quis in illa barbarie dubitet, quin ea Sphæra ſit perfecta ratione?* The ſumm of the Authors meaning is, "That there "were *Sun-dials* deſcribed, or drawn [with Lines, after the manner as our our Sun-dials are :] "and ſome made "with Water (which were the *Clepſydræ*;

*De Nat. Deor.* Lib. 2. § 34.

*dræ*, or Hour-glasses, before-mentioned.) " That *Posidonius* had lately contrived a Sphere, whose " Motions were the same in the " Sun, Moon, and 5 Planets, as were " performed in the heavens each day " and night.

The age wherein this Sphere was invented, was *Cicero*'s time, which was about 80 years before our Saviours birth.

And that it was a piece of Clock-work, is not (I think) to be doubted, if it be considered, that it kept time with those celestial bodies, imitating both their annual, and diurnal motions, as from the description we may gather it did.

It may be questioned, whether those Machines were common or not: I believe they were rarities then, as well as Mr *Watson*'s and others are accounted now. But methinks it is hard to imagine, that so useful an invention should not be reduc'd into common use; it being natural, and easie to apply it to the measuring of hours (tho unequal) especially in two such Ages, as those of *Archimedes* and *Tully* were, in which the liberal Arts so greatly flourished.

§ 6. After the times last mentioned, I find little worth remark, till the last age; in which Clock-work was revived, or wholly invented anew in *Germany*,

*many*, as is generally thought, because the ancient Pieces are *German* work. But who was the Inventer, or in what time, I cannot discover. Some think *Sever. Boethius* invented it about the year 510. Perhaps it was in *Regiomontanus* his time (if not so early as *Boethius*) which was above 200 years ago. It is very manifest, it was before *Cardan*'s time, because he speaketh of it, as a thing common then. And we lived about 150 years since. *Molyneaux, Scioth. Telescop. Ep. Dedic.*

§ 7. As to those curious contrivances in Clock-work, which perform strange, surprizing feats, I shall say little. Dr. *Heylin* tells us of a famous Clock and Dial in the Cathedral Church of *Lunden* in *Denmark*. "In "the Dial (saith he) are to be seen "distinctly the Year, Month, Week-"day, and hour of every day through-"out the Year; with the Feasts, "both moveable and fixed; together "with the Motion of the Sun and "Moon, and their passage thro each "degree of the Zodiack. Then for "the Clock, it is so framed by artificial "Engines, that whensoever it is to "strike, two Horse-men encounter "one another, giving as many blows "apiece, as the Bell sounds hours: "And on the opening of a door, there "appeareth a Theatre, the Virgin *Cosmog. l. 2*

"*Mary*

" *Mary* on a Throne, With Christ in
" her arms, and the three Kings or
" *Magi* ( with their ſeveral trains)
" marching in order, doing humble
" reverence, and preſenting ſeverally
" their Gifts ; two Trumpeters ſound-
" ing all the while, to adorn the Pomp
" of that Proceſſion.

*Magia Univerſ.* P. 1. *Proleg.* & *Magia Thaumaturg.*

To this I might add many more ſuch curious performances ; but I rather chuſe to refer the Reader to *Schottus*, where he may find a great variety, to pleaſe him.

# CHAP. VII.

## *Of the Invention of Pendulum Watches.*

§ 1. THe firſt that invented the way of applying Pendulums to Watch-work, was Mr *Christian Hugens* of *Zulichem* ; as he affirmeth of himſelf, with very cogent reaſons.

*Hor. Oſcil.* p. 3. Edit. Paris.

This excellent invention, he ſays, he put firſt in practice in the year 1657: and in the following year 1658, he printed a delineation and deſcription of it.

Others have claim'd the honor of this Invention; among which, the great *Galileo* hath the most to be said on his side. Dr. *John Joachim Becher* (who printed a Book when he was in *England*, entituled, *De Nova Temporis dimetiendi ratione Theoria, &c.* which he dedicated to the *English* Royal Society, *Anno* 1680.) he, I say, tells us, 'That the *Count Magalotti* '(the Great Duke of *Tuscany*'s Resident p. 8. 'at the Emperors Court) told him the 'whole History of these Pendulum 'Clocks, and denied Mr *Zulichem* to be 'the Author of them. Also, 'That one '*Treffler* (Clock-maker to the Father of 'of the then G. Duke of *Tuscany*) re-'lated to him the like History: and 'said moreover, that he had made the 'first Pend. Clock, at *Florence*, by the 'command of the Great Duke, and by 'the direction of his Mathematician '*Galilaus a Galilæo*; a pattern of which 'was brought into *Holland*. And fur-'ther he saith that one *Caspar Doms*, a '*Fleming*, and Mathematician to *John* '*Philip a Schonborn* (the late Elector of '*Mentz*) told him that he had seen at '*Prague*, in the time of *Rudolphus* the 'Emperor, a Pend. Clock, made by 'the famous *Justus Borgen*, Mechanick 'and Clockmaker to the Emperor: 'which Clock the great *Tycho-Brahe* 'used in his Astronomical observati-'ons.

Thus

Exper. made in the Acad. *del Cimento* transl. by Mr *Waller* p. 12.

Thus far *Becher*. To which I may add, what is said by the *Acadamie del Cimento*, *viz.* 'It was thought good to 'apply the Pendulum to the Movement 'of the Clock: a thing which *Galilæo* 'first invented, and his Son *Vincenzio Galilei* put in practice in the year 1649.

Hugen. ib.

As to these matters thus related by hearsay by *Becher*, and so expresly affirmed by the Acadamy, I have little to reply, but that Mr *Hugens* does expresly say, He was the Inventer, and that if *Galilæo* ever thought of any such thing, he never brought it to any perfection. It is certain, that this Invention never flourished till Mr *Hugens* set it abroad.

§ 2. After Mr *Hugens* had thus invented these Pendulum Watches, and caused several to be made in *Holland*, Mr *Fromantil*, a *Dutch* Clock-maker, came over into *England*, and made the first that ever were made here: which was about the year 1662. One of the first Pieces that was made in *England*, is now in *Gresham-Colledg*, given to that Honorable Society by the late eminent *Seth*, Lord Bishop of *Salisbury*: which is made exactly according to Mr *Zulichem*'s directions.

§ 3. For several years this way of Mr *Zulichem* was the only method, *viz.* Crown-wheel Pendulums, to play be-

between two cycloidal cheeks, *&c.* But afterwards Mr *W. Clement*, a *London* Clock-maker, contrived them (as Mr *Smith* saith) to go with less weight, an heavier Ball (if you please) and to vibrate but a small compass. Which is now the universal method of the Royal Pendulums. But Dr. *Hook* denies Mr. *Clement* to have invented this; and says that it was his invention, and that he caused a piece of this nature to be made, which he shewed before the *R. Society*, soon after the Fire of *London*.

*Horolog. Disquis.* p. 3.

§ 4. The use of these Pendulum Watches Mr *Hugens* setteth forth in several instances. Particularly; he giveth two examples of their great use at Sea, in discovering the difference of Meridians, more exactly than any other way: which he deduceth from the observations of an *English*, and *French* Ship.

On Land, they were found very serviceable, among other uses, particularly to these two. 1. To measure the time more exactly, and equally than the Sun. 2. To be (as Sir *Christoph. Wren* first proposed) a perpetual, and universal Measure, or Standard, to which all Lengths may be reduced, and by which they may be judged, in all ages, and countries. For (as our *Royal Society*, Mr *Hugens*, and *Mounto-*

*nus*

*nus* have proposed after Sir *Christopher Wren*) this *Horary foot*, or *Tripedal* length, which vibrateth Seconds, will fit all ages and places. But then respect must be had to the Center of Oscillation, which you have an account of in Mr *Hugens* his aforesaid book *de Horologio Oscillatorio*, as hath before been said.

§ 5. There is one contrivance more of Pendulums, still behind, *viz.* the *Circular Pendulum*: which is mentioned by Mr *Hugens* as his own, but is claimed by the ingenious Dr. *Hook* as really his. This Pend. doth not vibrate backward and forward, as those we have been speaking of do ; but always round round ; the String being suspended above, at the tripedal length, and the Ball fixed below, as suppose at the end of the Fly of a common Jack.

The motion of this Circular Pend. is as regular, and much the same with what goeth before : and was thus far made very useful in Astronomical observations, by the said Dr *Hook*, *viz.* To give warning at any moment of its circumgyration, either when it had turned but a quarter, half, or any lesser, or greater part of its circle. So that here you had notice not only of a Second, but of the most minute part of a Second of Time. You may find a description of this Pendulum, and other

other matters belonging to it, in Dr *Hook*'s *Lectiones Cutlerianæ* : *Animad. in Hevelii Mach. Cæleſt. p.* 60.

# CHAP. VIII.

## *Of the Invention of thoſe Pocket-Watches, commonly called Pendulum Watches.*

§ 1. THe reaſon they are called *Pendulum Watches*, is from the regularity of their Strokes, and Motion. Which exactneſs is effected by the government of a ſmall Spiral Spring running round the upper part of the Verge of the Ballance : which ſpring is called the *Regulator*.

§ 2. The firſt Inventer hereof, was that ingenious and learned member of our *R. Society*, Dr *Hook* : who contriv'd various ways of Regulation. One way was with a Load ſtone : another was with a tender ſtrait Spring, one end whereof played backward and forward with the Ballance. So that the ballance was to this Spring as the bob of a Pendulum, and the little Spring, as the Rod thereof. And ſeveral other contrivances he had beſides of this nature.

§ 3.

§ 3. But the Invention which beſt anſwered expectation, was at firſt, with two ballances: of which I have ſeen two ſorts, altho there were ſeveral others. One way was without Spiral Springs, the other with. They both agreed in this, that the outward Rims of both the Ballances, had a like number of Teeth; which running in each other, cauſed each Ballance to vibrate alike.

But as to the former of theſe, which had no Spiral Spring; the Verges of its Ballances had each but one Pallet apiece, about the middle of the Verge. The Crown-wheel lay (contrary to others) reverſed, in the middle of the Watch, in the place, and after the manner of the Contrate-wheel. The teeth of this Crown-wheel, were cut after the manner of Contrate-wheel teeth, *viz.* lying upwards, but very wide apart, ſo as that the Pallets (which were about one tenth of an inch long, and narrow) might play in and out between each tooth. The verges of the two Ballances, were ſet one on one ſide, the other on the other ſide of the Crown-wheel, ſo that the Pallets might play freely in its teeth. And when the Crown-wheel in moving round, had delivered its ſelf of one Pallet, the other Pallet on the oppoſite ſide, was drawn on to make its Beat, by means

of

of the motion which the other Ballance had given its Ballance, (the two Ballances moving one another, as hath been ſaid in the beginning of this Paragraph.) And ſo the ſame back again.

It may here be noted, that for the more clear underſtanding of the laſt contrivance, I have deſcribed the two Ballances, as having Teeth on the edges of their Rims, running in one another. But the contrivance was really thus, there was a ſmall Wheel under each Ballance, proportioned to the width of the Crown-wheel. But the Ballances were much larger. And ſo the Teeth of theſe two little foreſaid Wheels or Ballances, running in one another, moved the larger Ballances above them, all one, as if theſe two great Ballances had been toothed and played in each other.

§ 4. The other way, with two Ballances alſo, moving each other (as was ſaid in the beginning of the laſt §) had a Spiral Spring to each Ballance, for its Regulator. In this Invention, only one Ballance had the Pallets, as the common Ballances have: and the Crown-wheel operated upon it, according to the uſual way. But then when this Ballance vibrateth, it giveth the ſame motion backward and forward to the other ballance; as hath been ſaid.

The

The first of these two ways was never prosecuted so far, as perhaps it deserved. And the excellency of the latter is, that no jirk, or the most confused shake, can in the least alter its Vibrations. Which it will do in the best Pendulum Watch with one ballance now commonly used. For if you lay one of these Watches upon a Table, and by the Pendant jirk it backward and forward, you will put it into the greatest hurry; whereas the last mentioned Watch, with two ballances, will be nothing affected with it. But notwithstanding this inconvenience, yet the Watch with one ballance and one Spring (which was also Dr *Hook*'s Invention) prevailed, and grew common, being now the universal Mode: but of the other very few were ever made. The reason hereof, I judge was the great trouble and vast niceness required in it, and perhaps a little foulness in the ballance-teeth may retard the motion of the ballances. But the other is easier made, and performeth well enough, and in a pocket is scarce subject to the aforesaid disorder, which is caused rather by a turn, than a shake.

§ 5. The time of these Inventions was about the year 1658, as appears (among other evidence) from this inscription,

ſcription, upon one of the aforeſaid double Ballance-Watches, preſented to King *Charles* II. *viz. Robert Hook inven.* 1658. *T. Tompion fecit* 1675.

This Watch was wonderfully approved of by the King; and ſo the invention grew into reputation, and was much talked of at home and abroad. Particularly its fame flew into *France*, from whence the Dauphine ſent for two; which that eminent Artiſt Mr *Tompion* made for him.

§ 6. Dr *Hook* had long before this, cauſed ſeveral pieces of this nature to be made, altho they did not take till after 1675. However he had before ſo far proceeded herein, as to have a Patent (drawn, tho not ſealed) for theſe, and ſome other Contrivances, about Watches, in the year 1660. But the reaſon why that Patent did no further proceed, was ſome diſagreement about ſome Articles in it, with ſome Noble Perſons who were concerned for the procuring it. The ſame ingenious Dr had alſo a grant for a Patent for this laſt way of Spring Watches in the year 1675: but he omitted the taking it out, as thinking it not worth the while.

§ 7. After theſe Inventions of Dr *Hook*, and (no doubt) after the publication of Mr *Hugens* book *de Horolog.* *Oſcil.*

*Oscil.* at *Paris* 1673 (for there is not a word of this, tho of several other contrivances) after this, I say, Mr. *Hugens* Watch with a Spiral Spring came abroad, and made a great noise in *England*, as if the Longitude could be now found. One of these the Lord *Bruncker* sent for out of *France*, (where Mr *Hugens* had a Patent for them) which I have seen.

This Watch of Mr *Zulichem*'s agreed with Dr *Hook*'s, in the application of the Spring to the ballance: only Mr *Zulichem*'s had a longer Spiral Spring, and the Pulses or Beats were much slower. That wherein it differs, is 1. The Verge hath a Pinion instead of Pallets; and a Contrate-wheel runs therein, and drives it round, more than one turn. 2. The Pallets are on the Arbor of this Contrate-wheel. 3. Then followeth the Crown-wheel, *&c.* 4. The ballance, instead of turning scarce quite round (as Dr *Hook*'s) doth turn several rounds every vibration.

§ 8. As to the great abilities of Mr *Hugens*, no man can doubt, that is acquainted with his Books, and his share in the Philosophical Transactions, *&c.* But I have some reason to doubt, whether his Fancy was not first set on work by some Intelligence, he might have of Dr *Hook*'s Invention from Mr

Ol-

*Oldenburg*, or others his correſpondents here in *England.*

But whether or no that ingenious perſon doth owe any thing herein to our ingenious Dr *Hook*, it is however a very pretty, and ingenious contrivance; but ſubject to ſome defects: *viz.* When it ſtandeth ſtill, it will not vibrate, until it is ſet on vibrating: which, tho it be no defect in a Pendulum Clock, may be one in a Pocket-Watch, which is expoſed to continual jogs. Alſo, it doth ſowewhat vary in its Vibrations, making ſometimes longer, ſometimes ſhorter turns, and ſo ſome ſlower, ſome quicker vibrations.

I have ſeen ſome other contrivances of this ſort, which I mention not, becauſe they are of a younger ſtanding. But theſe two (of Dr *Hook* and Mr *Hugens*) I have taken notice of, becauſe they were the firſt that ever appeared in the world.

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## CHAP. IX.

### *The Invention of Repeating Clocks.*

1. THe *Clocks* I now ſhall ſpeak of, are ſuch as by pulling of a

 String,

String, *&c.* do ſtrike the Hour, Quarter, or Minute, at any time of the day and night.

§ 2. Theſe Clocks are a late invention of one Mr *Barlow*, of no longer ſtanding than the latter end of King *Charles* II. about the year 1676.

This ingenious contrivance (ſcarce ſo much as thought of before) ſoon took air, and being talked of among the *London* Artiſts, ſet their heads to work; who preſently contrived ſeveral ways to effect ſuch a performance. And hence aroſe the divers ways of *Repeating work*, which ſo early might be obſerved to be about the Town, every man almoſt practiſing, according to his own Invention.

§ 3. This invention was practiſed chiefly, if not only, in larger movements, till King *James* II's Reign: at which time it was transferred into Pocket-Clocks. But there being ſome little conteſt concerning the Author hereof, I ſhall relate the bare matter of fact, leaving the Reader to his own judgment.

About the latter end of King *James* II's Reign, Mr *Barlow* (the ingenious inventer before mentioned) contrived to put his invention into Pocket-watches; and endeavoured (with the Lord Chief Juſtice *Allibone*, and ſome others)

others) to get a Patent for it. And in order to it, he ſet Mr *Tompion*, the famous Artiſt, to work upon it: who accordingly made a Piece according to his directions.

Mr *Quare* (a very ingenious Watch-maker in *London*) had ſome years before been thinking of the like Invention: but not bringing it to perfection, he laid by the thoughts of it, until the talk of Mr *Barlow*'s Patent revived his former thoughts; which he then brought to effect. This being known among the Watch-makers, they all preſſed him to endeavour to hinder Mr *Barlow*'s Patent. And accordingly applications were made at Court, and a Watch of each invention, produced before the King and Council. The King upon tryal of each of them, was pleaſed to give the preference to Mr *Quare*'s: of which, notice was given ſoon after in the Gazette.

The difference between theſe two Inventions was, Mr *Barlow*'s was made to Repeat by puſhing in two pieces on each ſide the Watch-box: one of which Repeated the Hour, the other the Quarter. Mr *Quare*'s was made to Repeat, by a Pin that ſtuck out near the Pendant; which being thruſt in (as now 'tis done by thruſting in the Pendant) did Repeat both the Hour,

and Quarter; with the ſame thruſt.

It would (I think) be very frivolous, to ſpeak of the various contrivances, and methods of Repeating work, and the Inventers of them; and therefore I ſhall ſay nothing of them.

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## CHAP. X.

### *Numbers for ſeveral ſorts of Movements.*

I Think it may be very convenient to ſet down ſome Numbers fit for ſeveral Movements; partly, to be as Examples to exerciſe the young Reader, in the foregoing Art of Calculation: and partly, to ſerve ſuch, who want leiſure or underſtanding to attain to this Art.

§ 1. But firſt it may be requiſite, to ſhew the uſual way of Watch-makers writing down their numbers, which is ſomewhat different from that in the preceding Book.

Their way repreſenteth the Wheel and Pinion, on the ſame Spindle; not as they play in one another. Thus the numbers of an old Houſe-watch, of 12 hours, is written thus;

| My way : | The Watch-makers way. |
|---|---|
| 4)48 | 48 |
| 7)56 | 56 — 4 |
| 6)54 | 54 — 7 |
| 19 | 19 — 6 |

According to my way, the Pin. of Report [4] drives the Dial-wheel [48:] the Pinion [7]plays in the Great-wheel [56] *&c.* But according to the other way, the Dial-wheel ſtands alone ; the Great-wheel hath the Pinion of Report on the ſame arbor : the Wheel [54] hath the Pin : [7] and the Crown-wheel [19] the Pin : [6] on the ſame Spindles.

This latter way (tho very inconvenient in Calculation) repreſenteth a piece of work handſomely enough, and ſomewhat naturally.

§ 2. Numbers of an 8 day Piece, with 16 turns of the Barrel, the Pend. vibrates Seconds, and ſhews Minutes, Seconds, *&c.*

| The Watch-part. | The Clock part. |
|---|---|
| 8)96 | 8)78 |
| 8)60—48)48—6)72 | 6)48 8 pins. |
| 7)56 | 6)48 |
| — | 6)48 |
| 30 | |

In the Watch-part, the Wheel 60 is the Miuute-wheel, which is ſet in the middle of the Clock, that its Spindle

may go thro the middle of the Dial-plate to carry the Minute-hand.

Alſo on this Spindle is a Wheel 48, which driveth another Wheel of 48, which laſt hath a Pinion 6, which driveth round the Wheel 72 in 12 hours. Note here two things: 1. That the two Wheels 48, are of no other uſe, but to ſet the Pinion 6 at a convenient diſtance from the Minute-wheel, to drive the Wheel 72, which is concentrical with the Minute-wheel. For a Pinion 6 driving a Wheel 72, would be ſufficient, if the Minute-hand and Hour-hand had two different centers. 2. Theſe numbers, 60-48)48-6)72, ſet thus ought (according to the laſt §) be thus, read, *viz.* The Wheel 60, hath another Wheel 48 on the ſame Spindle; which Wheel 48 divideth (playeth in, or turns round) another Wheel 48; which hath a Pinion 6 concentrical with it: which Pinion driveth, or divideth a Wheel of 72. For a Line parting two numbers (as 60 —— 48) denoteth thoſe two numbers to be concentrical, or to be plac'd upon the ſame Spindle. And when two numbers have a hook between them (as 48)48) it ſignifies one to run in the other, as hath before been hinted.

In the Striking-part, there are 8 Pins on the Second wheel 48. The Count-wheel

wheel may be fixed unto the Great-wheel, which goeth round once in 12 hours.

§ 3. A Piece of 32 days, with 16, or 12 turns both parts: the Watch sheweth Hours, Minutes, and Seconds; and the Pendulum vibrateth Seconds.

The Watch-part.

| With 16 turns. | With 12 turns. |
|---|---|
| 16)96 | 12)96 |
| 9)72 | 9)72 |
| 8)60--48)48--6)72 | 8(60--48)48--6)72 |
| 7)56 | 7)56 |
| — | — |
| 30 | 30 |

Or thus with 16 turns.

12)72
8)64
8)60
7)56
—
30

The Striking part.

| With 16 turns. | With 12 turns. |
|---|---|
| 10)130 | 8(128 |
| 8)96 { 24 pins<br>12)39 | 8)104 { 26 pins<br>8)24 |
| 6)72 Double hoop. | 8)96 Double hoop |
| 6)60 | 8)80 |

The Pinion of Report is fixed on the end of the arbor of the Pin-wheel. This Pinion in the first is 12, the Count-wheel 39; thus, 12)39. Or it may be 8)26. In the latter (with 12 turns) it may be 6)18, or 8) 24.

§ 4. *A two month Piece*, of 64 days; with 16 turns; Pend. vibrateth Seconds; and sheweth Minutes, Seconds, *&c.*

| Watch part. | Clock-part. |
|---|---|
| 9)90 | 10)80 |
| 8)76 | 10)65 |
| 8)60--48)48--6)72 | 9)54 { 12 pins. |
| 7)56 | — 8) 52 |
| —— | 5(60-DoubleHoop |
| 30 | 5)50 |

Here the third Wheel is the Pin-wheel, which also carrieth the Pinion of Report 8, driving the Count-wheel 52.

Or thus

| Watch-part. | Clock-part: |
|---|---|
| 8)80 | 6)144 |
| 8)76 | 6)78 { 26 pins |
| 8)60-48)48-6)72 | — 8)24 |
| 7)56 | 6)72-Double Hoop |
| —— | 6)60 |
| 30 | |

§ 5. A piece of 13 weeks, with Pendulum, Turns, and Motions, as before.

The

The Watch-part.

| | |
|---|---|
| 8)96 Or thus | 6)72 |
| 8)88 | 6)66 |
| 8)60--48)48--6)72 | 6)48--48)48--6)72 |
| 7)56 | 6)45 |
| 30 | 30 |

The Clock-part.

| | |
|---|---|
| 8)72 Or thus. | 5)145 |
| 8(64 — 37)30 | 6)90 { — 30 pins |
| 8)48—12 pins | — 24)62 |
| 6(48 Double hoop | 6)72 |
| 5)40 | 6)60 |

§ 6. A *Seven Month* Piece, with Turns, Pendulum, and Motions, as before.

| The Watch. | The Clock. |
|---|---|
| 8)60 | 8)96 |
| 8)56 | 8)88—27(12 |
| 8)48 | 8)64—16 pins |
| 6)45- 48)48-6)72 | 6)48 Double hoop |
| 5)40 | 6)48 |
| 30 | |

§ 7. *A Year Piece*, of 384 days, with Turns, Pendulum, and Motions, as before.

| The Watch. | The Clock. |
|---|---|
| 12)108 | 10)120 |
| 9)72 | 8)96—36)9 |
| 8)64 | 6)78 26 pins |
| 8)60--48)48-6)72 | 6)72 Double hoop |
| 7)56 | 6)60 |
| 30 | |

If you had rather have the Pinion of Report, on the Spindle of the Pin wheel it must be 13)39.

§ 8. A Piece of 30 Hours, Pend. about 6 inches.

| The Watch. | The Clock. |
|---|---|
| 12)48 | 8)48 |
| —— | —— |
| 6)78 | 6)78 13 pins |
| 6)60 | 6)60 |
| 6)42 | 6)48 |
| —— | |
| 15 | |

§ 9. A Piece of 8 days, with 16 turns, *Pendulum* about 6 inches, to shew Minutes, Seconds, *&c.*

| The Watch. | The Clock may |
|---|---|
| 8)96 | be the same |
| 8)64—48)48—6)72 | with the 8 day |
| 8)60 | piece before, |

8)40 The Seconds Wheel. § 2.

——

15

§ 10. A *Month Piece* of 32 days, with Pendulum, Turns, and Motions, as the last.

The

| The Watch. | The Clock may have the same numbers, as the Clock § 3. |
|---|---|
| 8)64 | |
| 8)48 | |
| 6)48 — 48)48 — 6)72 | |
| 6)45 | |
| 6)30 Seconds Wheel. | |
| —— | |
| 15 | |

§ 11. A *Year Piece* of 384 days with Pendulum, Turns, *&c.* as the last.

The Watch part.

| | Or thus, with a Wheel less, not to shew Minutes and Seconds. |
|---|---|
| 10)90 | |
| 8)64 | |
| 7)56 | |
| 6)48 — 48)48 — 6(72 | 8)96 |
| 6)45 | 6)72 — 36)9 |
| 6)30 Seconds Wheel. | 6)66 |
| | 6)60 |
| —— | 6(54 |
| 15 | —— |
| | 19 |

In the latter of these two Numbers, the Pinion of Report is 36, on the Second Wheel. The Dial Wheel is 9.

The *Clock part* may have the same Numbers, as the Year-piece before § 7.

§ 12. An 8 *Day* Piece, to shew the Hour and Minute, *Pend.* about 3 *inches* long.

6)96

6)96
8)64--6)72
7)49
6)36

19

The Clock may have the same numbers, as the 8 day piece before § 2.

## *Automata shewing the Motion of the Celestial Bodies.*

§ 1. Numbers for the Motion of the *Sun* and *Moon*. See before in Chap. 2. Sect. 5. § 3, 4.

§ 2. Numbers to shew the Revolution of the Planet *Saturn*, which consists of 10759 days.

On the Dial-wheel.
5)69
4)52
4)48
4)40

If you would make it depend upon a wheel going round in a year thus, 10)59 6)30 or thus, 4(118.

*Note*, The lowermost Pinion in these, and the following numbers, is to be fixed concentrical to the Wheel, which is to drive the Motion, *viz.* the Dial-wheel. Year-wheel, or *&c.*

§ 3. Numbers for the Planet *Jupiter*, whose Revolution is 4332 $\frac{1}{2}$ days,

On the Dial-wheel.

4)48 Or thus, on the Year-wheel.
4)40 6)71
4)36
4)32

Note here, That the two last numbers of *Saturn*, may be the two first of *Jupiter* also.

By the permission of my ingenious friend Mr *Flamsteed*, I here insert a description of Mr *Olaus Romer*, the *French* King's Mathematician's instrument, to represent the motion of *Jupiter's Satellites*; a copy of which he sent to Mr *Flamsteed* in 1679.

Upon an axis (which turns round once in 7 days) are four whee s fixed: one of 87 teeth, a second of 63; the third 42; and the last 28 teeth. On another axis run 4 other Wheels (or Pinions you may call them) which are driven by the aforesaid Wheels. The first is a Wheel, or Pinion of 22 leaves driven by the Wheel 87, which carrieth round the first Satellite. The Second is 32, driven by the Wheel 63, which carrieth round the second Satellite. The third hath 43 leaves, driven by the Wheel 42, which carrieth the third Satellite. And lastly, is the Pinion 67, driven by the Wheel 28, which carrieth round the fourth Satellite.

On

On the first axis is an Index, that pointeth to a circle divided into 168 parts, which are the hours in seven days.

On the other axis all the Pinions run concentrically, by means of their being hollow in the middle. In the midst of them all, the axis of *Jupiter* himself is fixed, with a little Ball at the top, representing *Jupiter*'s body. On the ends of 4 small Wires, fixed in the four several Sockets of the aforesaid Pinions, may 4 lesser Globules be plac'd (at their due distance from *Jupiter*'s Globule) to represent the 4 Satellites going round that Planet.

§ 4. Numbers for *Mars*, whose Revolution is 1 year 322 days.

On the Dial-wheel.

| | |
|---|---|
| 4)48 | The two last Numbers of *Saturn* may be the two first of *Mars* also. |
| 4)40 | |
| 4)45 | |

§ 5. Numbers for *Venus*, whose Revolution is in 224 days.

On the Dial-wheel.

| | |
|---|---|
| 4)32 | *Note*, The last number of *Jupiter* may be the first of *Venus*. |
| 4)32 | |
| 4)28 | |

§ 6. Numbers for *Mercury*, whose Revolution is near 88 days.

On

On the Dial wheel.

4(56
4)52

§ 7. Numbers to represent the Motion of the *Dragon's Head* and *Tail*, (near 19 years) to shew the *Eclipses* of the Sun and Moon.

On the Dial-wheel. On the Year-wheel.

4)48 4)76
4)40 Note, the two last numbers
4)44 of *Saturn* may be the two
4)42 first of this on the Dial-wheel.

As to the placing these several motions on the Dial-plate, I shall leave it wholly to the Workman's contrivance. He may perhaps make them to represent the *Copernican*, or some other System.

*Numbers for Pocket Watches.*

§ 1. A Watch to go 8 *Days*, with 12 turns, to shew Minutes and Seconds; the Train 16000.

6)96
6)48—12)48—12)36.
6)45 On the Wheel [42] is the Se-
6)42 cond's hand placed, and on the
19 Wheel [48] the Minute hand.

§ 2. Another of the ſame, without Minutes and Seconds, to go with only 8 turns.

20)10

———

6(66
6)60
5)50
5)45

———

19

§ 3 A Pocket-watch of 32 *Hours*, with 8 turns, to ſhew Minutes and Seconds, Train as the laſt.

12)48
6)48 — 12)48 — 12)36
6)45 — Seconds Hand.

———

19

If this Crown-wheel be too large you may uſe theſe numbers, *viz*.

12)48
6)48
6)45
6)48 Seconds hand.

———

15

§ 4. The usual Numbers of 30 hours Pendulum Watches, with 8 turns, to shew the Hour and Minute.

12)48
6)54 —— 12)48 —— 12)36
6)48
6)45
——
15

§ 5. The usual Numbers of the old 30 hours Pocket-watches.

| With 5 Wheels. | With 4 Wheels. |
|---|---|
| 10)30 | 6)32 |
| —— | —— |
| 7)63 | 6)66 |
| 6)42 | 5)50 |
| 6)36 | 5)45 |
| 6)32 | —— |
| —— | 17 |
| 15 | |

If any of the Numbers of the preceding Wheels and Pinions should not please the Reader, he may easily correct them to his mind, by the Instructions in the foregoing Book. The way in short is this: Divide the Wheel by the Pinion, and so find the number of turns, according to the Chap. 2. Sect. 1. § 2. Multiply the Pinion you like better, by this number of turns, and the Product is the Wheel. Thus in the 8 day Pocket-watch § 1, if you think the Great-wheel too large, you may

may make it inſtead of 6)96(16, thus, *viz:* 5)80(16 : *i. e.* chuſing the Pinion only 5, and multiplying it by 16 (the turns) the Wheel will be 80.

---

## CHAP. XI.

### *Tables of Time relating to Watch work.*

**A Table of Time.**

| Seconds. | | | | | | |
|---|---|---|---|---|---|---|
| 60 | Minutes | | | | | |
| 3600 | 60 | Hours. | | | | |
| 86400 | 1440 | 24 | Day. | | | |
| 604800 | 10080 | 168 | 7 | Week. | | |
| 2592000 | 43200 | 720 | 30 | 4 | Month | |
| 31536000 | 525600 | 8760 | 365 | 52 | 12 | Year |

The foregoing Table will be of good uſe in Calculation, for the ready finding out the parts of time: which is thus. Find the parts of time you ſeek for, the number in the concurrence of Squares, is the anſwer to your queſtion. Thus ſuppoſe you ſeek for the number of Seconds in a Year: in the Square under *Seconds*, and in the ſame line with Year (which is the lowermoſt Square on the

left

left hand) is the number sought, *viz.* 315, *&c.* So Minutes in a Month, are 43200.

If you would know any number, where there is the addition of an odd number to it, as the Seconds in a month and one day; add the Seconds in a month (which are 259—) and the Seconds in a day (which are 86—) and you have the Number sought, *viz.* 2678400.

*A Table to set a Watch by the Fixed Stars.*

| Night | Hour. | Min. | Sec. | Night | Hour. | Min. | Sec. |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 3 | 57 | 16 | 1 | 3 | 20 |
| 2 | 0 | 7 | 54 | 17 | 1 | 7 | 17 |
| 3 | 0 | 11 | 51 | 18 | 1 | 11 | 14 |
| 4 | 0 | 15 | 47 | 19 | 1 | 15 | 11 |
| 5 | 0 | 19 | 44 | 20 | 1 | 19 | 8 |
| 6 | 0 | 23 | 41 | 21 | 1 | 23 | 5 |
| 7 | 0 | 27 | 38 | 22 | 1 | 27 | 1 |
| 8 | 0 | 31 | 35 | 23 | 1 | 30 | 58 |
| 9 | 0 | 35 | 32 | 24 | 1 | 34 | 55 |
| 10 | 0 | 39 | 29 | 25 | 1 | 38 | 52 |
| 11 | 0 | 43 | 26 | 26 | 1 | 42 | 49 |
| 12 | 0 | 47 | 23 | 27 | 1 | 46 | 46 |
| 13 | 0 | 51 | 29 | 28 | 1 | 50 | 43 |
| 14 | 0 | 55 | 26 | 29 | 1 | 54 | 40 |
| 15 | 0 | 59 | 22 | 30 | 1 | 58 | 26 |

Ex-

*Explanation of the Table.*

This Table ſhews how much the Sidereal goeth faſter than the Solar day, in any number of nights for a month. So that obſerving by your Watch, the nice time when any fixed Star cometh to the Meridian, or any other point of the Heavens: if after one Revolution of that ſame Star to the ſame point, your Watch goeth 3′. 57″ ſlower than the Star; or after two nights 7′. 54″; or 16 nights, 1 hour 3′. 20″, &c. then doth your Watch keep time rightly with the Mean motion of the Sun. If it vary from the Table, you muſt alter the length of your Pendulum to make it ſo keep time.

To obſerve the time nicely, when the Star cometh again to the ſame point of the Heavens 'tis neceſſary to make the obſervation with a Teleſcope, that hath croſs threads in the focus of the object glaſs; and ſo leaving the Teleſcope fixed on the ſame poſture, till a ſecond obſervation. You may do this with the Teleſcopular ſights of a Quadrant, or Sextans, or any other Teleſcope, and ſo leaving it ſtanding until another night of obſervation. Or for want of this more nice way, you may do it by looking along by the edge of two Strings, ſuſpended with Plumbets, in a room, at ſome diſtance from one ano-

another. Or by looking at the edge of a Chimney, *&c.* as Mr *Watſon* hath directed, at the end of Mr *Smith's Horol. Diſquiſ.* But to make a tolerable obſervation any of theſe laſt ways, 'tis neceſſary to have a Candle ſhine upon the edge of the furthermoſt String, or Chimney; without which you cannot ſee exactly when the Star cometh thereto.

*A Table ſhewing the Variations made in the true Hour of the Day, by the Refraction of the Sun in the Equator, and both the Solſtices.*

| Sun's altitude Deg | Sun's Refraction. ′ ″ | Variation at the N. Solſtice. ′ ″ | Variation at the Equator. ′ ″ | Variation at the S. Solſtice. ′ ″ |
|---|---|---|---|---|
| 00 | 33 00 | 4 34 | 3 32 | 4 38 |
| 1 | 23 00 | 2 34 | 2 28 | 3 19 |
| 2 | 17 00 | 2 24 | 1 49 | 2 31 |
| 3 | 13 30 | 1 46 | 1 27 | 2 3 |
| 4 | 11 30 | 1 29 | 1 12 | 1 40 |
| 5 | 9 30 | 1 12 | 1 1 | 1 33 |
| 6 | 7 30 | 0 56 | 0 49 | 1 17 |
| 7 | 7 00 | 0 52 | 0 44 | 1 16 |
| 8 | 6 00 | 0 43 | 0 39 | 1 8 |
| 9 | 5 00 | 0 36 | 0 34 | 1 2 |
| 10 | 4 40 | 0 25 | 0 29 | 1 2 |

*Remarks*

## Remarks upon the Table.

TheColumn of the SunsRefractions, I owe to that accurate obſerver of the celeſtial motions, Mr *Flamſteed*. Which Refractions,altho in the Table they are the ſame, yet do differ at different ſeaſons of the year, nay perhaps, according to the different temperature of the air ſometimes,in the ſame day. Thus Mr *Flamſteed* found the Refractions in *February*, very different from thoſe in *April*: and it is obſerved, that the Refractions are commonly greater, when the *Mercury* is higher in the Barometer.

The Table therefore doth not ſhew what the Refractions always are, but only about the middle quantity of them, at every degree, of the 10 firſt of the Sun's altitude. And accordingly I have calculated the variations thereby made in the hour of the day.

Theſe variations of the hour are greater or leſſer, according as the angle of the Sun's diurnal motion is acuter with the horizon. The reaſon is plain; becauſe as the Sun appears by refraction higher than really he is; ſo this falſe height doth affect the hours in Winter, more than the Summer half year.

There is no ray indeed of the Sun, but

but what cometh refracted to a Sun-dial, and consequently, there is no Dial but what goeth more or less false (except at Noon in Dials that cast a Shade, where the refraction makes no variation.) But the Refraction decreaseth apace, as the Sun gets higher, and causeth a variation of not above half a minute at 10 degrees of the Sun's altitude; except when the Sun is in, or near the Southern Tropick; Nearer than half a minute, few common Sun-dials shew the time. And therefore partly for this reason, and partly, because Mr *Flamsteed*'s observations reach not much farther, I have calculated my Table to only 10 degrees.

The Table needs little explication. For having the Sun's height, you have against it, in the next Column, the Refraction: and in the 3 next the alterations of the hour, at 3 times of the year. Taking therefore by a Quadrant the Sun's altitude, and observe at the same time, the hour of the day by a Sun-dial, by the Table, you see how many minutes, and seconds, the Dial is too fast. As at the Sun-rising a Sun-dial is too fast 4'. 34", about *June* 11, and 3'. 32", about *Mar.* 10. and *Sept.* 12, and 4' 38" about *Dec.* 11.

# A SUPPLEMENT TO THE TREATISE OF *Watch & Clock-work*, CALLED The Artificial Clock-Maker.

Wherein is Contain'd,

1. The Anatomy of a Watch and Clock.
2. Monsieur *Romer*'s Satellite-Instrument: with Observations concerning the Calculation of the Eclipses of *Jupiter*'s *Satellites*, and to find the *Longitude* by them.
3. A nice way to correct *Pendulum Watches*.
4. Mr *Flamsteed*'s Equation Tables.
5. To find a *Meridian-Line* for the Governing of Watches, and other Uses.
6. To make a *Telescope* to keep a Watch by the Fixed Stars.

By *W. D.* M. A.

*LONDON*,
Printed for *James Knapton*, at the *Crown* in St *Paul*'s Church-yard. 1700.

# TO THE
# READER,

*UPon a review of my Book, in order to another Edition, I have thought it necessary to add some things, and to make some small amendments in the body of the Book it self.*

*And because I think it a piece of justice owing to the Buyers of the first Edition, that I should endeavour, as much as I can, to make their Edition as compleat as this; therefore, instead of inserting what this Supplement contains into proper places of the Book, I have rather chosen to put it rhapsodically together; and taken care that it be printed so, as to be bought by itself at a small price.*



*Also*

*Also I think my self obliged, to be at the pains to collect the most material alterations, and amendments which I have made in my Book, and here to insert them in this Supplement; whereby the Reader may supply with his Pen (if he pleaseth) what is wanting in the first Edition.*

*The Purchasers both of the first and of this Edition will (we hope) excuse both the Bookseller and me, for reducing this Edition into a lesser Volume, that it may be more portable for the Pocket, and (we hope) both Book and Supplement too, cheaper; at least, not dearer than the first Edition, for the benefit of poor workmen.*

*Pas-*

# Passages wanting in the first Edition.

PAge 5. line 2. after pocket-watches, add [and others] l. 4. after wheels, add [whence it hath its Name] l. penult. dele [somtimes.]

P. 7. After l. 11. add [the Train is the Number of Beats which the Watch maketh in an hour, or any other certain time.]

P. 10. l. 24. after *Wheel* 40, add [which runs concentrical, or on the same arbor with the second Pinion 5.]

P. 12. l. 3. after has, add [as hath been said.]

P. 15. l. 15. add in the Margin [see Sect. 1. §. 3.]

L. 23. In the margin add [See Sect. 1. §. 4.]

P. 19. l. 6. add in the Margin [See §. 4.]

P. 20. l. 20. for 2196. r. 20196.

P. 25. l. 2. after *Report* add [fixed on the Great-wheel.]

P. 28. l. 9. add in the Margin [Sect. 1. §. 3.]

P. 30. l. 22. in the Margin add [§. 7]

P. 34. l. 14. after *Report* add [and the Count-wheel.].

P. 35. l. 12 after *Rules*, add [*To find how many strokes the Clock striketh in one turn of the Fusy, or Barrel.*

L. 19. after *Rule* 2. add [*To find how many days the Clock will go.*]

L. 27. after *Rule* 3. add [*To find the number of turns of the Fusy or Barrel.*]

P. 36. l. 21. after *Rule* 4. add [*To fix the Pin. of Report on the Spindle of the Great-wheel.*]

P. 38. l. 8. after turns, add [of the Fusy.]

L. 25. after *Then*, add [(if you make the Great-wheel the Pin-wheel.)]

P. 53. l. 9. after *Motions*, add [in Watch-work]

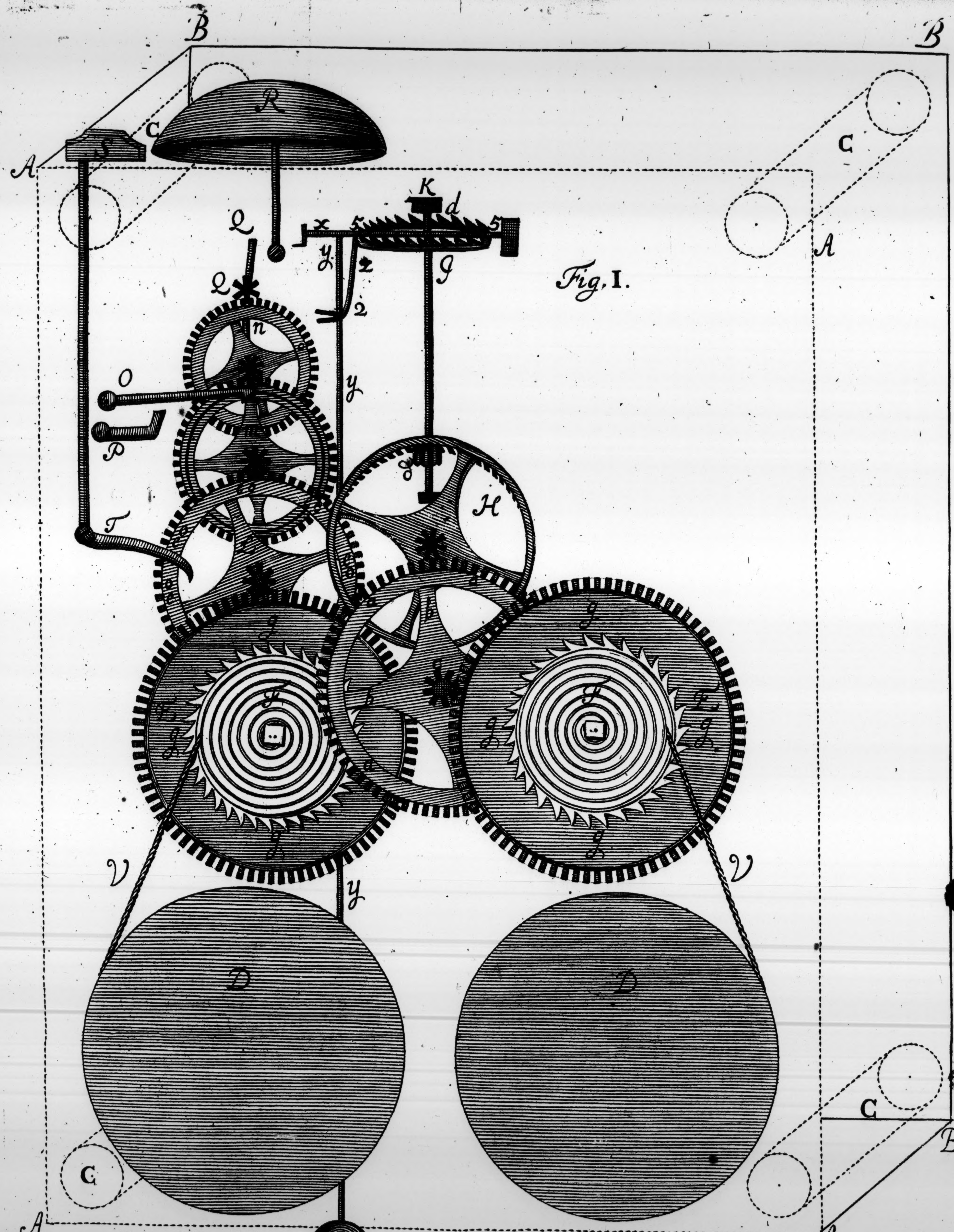
P. 57. l. 17. amend thus [10)59(5.9]

P. 58. l. 26. r. [round by a]

P 75. l. penult. after *To the*, add [square of the.]

P. 112. l. 20. add [or thus with 16 turns.]

12)72
8)64
8)60
7)56
———
30




Page 5.th in the Appendix.

P. 122, to § 3. add [if this Crown-wheel be too large you may use these numbers, *viz.*

12)48
6)48
6(45
6)48 Seconds-hand

15

P. 126. l. 24 after *Sextans*, add [or any other Telescope.]

P. 132. l. 15. after 2. add [by the directions in Chap. 2. Sect. 2. §. 5]

L. 18. after *If* add [as in the Movements in *ch.* 10.]

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I.

## *An Explication of the Figures.*

*Fig.* 1. Representeth the parts of a *Watch* and *Clock* described in the Book, *Ch.* 1.

The Wheels, *&c.* on the right hand, is the *Watch*-part. They on the left, the *Clock-part*.

A. A. A. A. The upper *Plate* of the *Frame*: which you may imagine to be transparent (as of glass) to admit of a Prospect of the Wheel-work underneath it.

B. B. B. The lower *Plate* of the *Frame*.

C. C. C. C. The *Pillars*.

D. D. The *Spring-Boxes* of the Watch, and Clock-part.

E. E. The *Great-wheel* of each part.

F. F. The *Fusy* of each part, about which the Chain, or String is wrapped.

g.g. g. g. g. g. g. The *Ratchet* of each part.

a.a. a. The *Hoop*, or *Rim* of the *Second wheel.*

b. b. The *Cross* thereof.

c. The *Pinion.*

H. The *Contrate-wheel.*

I. The *Crown-wheel.*

d. d. The upper and lower *Pevet* thereof.

K. A piece of Brass, in which the *Pevet-hole* is, in which the *Pevet* d. playeth.

L. The *Pin-wheel*, with the *Striking-Pins* e. e. e. e. e.

M. The *Detent-wheel.*

N. The *Warning wheel*, or fourth wheel.

O The *Detent.*

P. The *Lifting-piece.*

Q. Q. The *Fan*, and *Flying-Pinion.*

R. The *Bell.*

S. The *Hammer.*

T. The *Hammertail.*

V. V. The Chain, or String of the Watch, and Clock.

x. The *Verge* or *Spindle* of the Ballance, or Pendulum.

y. y. y. The *Rod* of the Pendulum.

z. The *Fork.*

2. The *Flatt.*
3. The *Great-Ball.*
4. The *Corrector* or *Regulator.*
5. 5. The *Pallets.*

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## II.
### *Fig.* 2.

Rerpresenteth the *Satellite Instrument* of *Monſ. Olaus Romer*, deſcribed in the Book, page 109.

A. B. the upper Plate of the Inſtrument.

C. D. The lower Plate.

K. L. An *Axis*, or *Spindle*, on which four wheels are fixed, and turn round with it, and with the Hand L. once in 7 days. E. F. G. H. are the *Sockets*, or hollow *Arbors* of 4 wheels running concentrically.

The hollow Arbor H. carrieth round the *Firſt-Satellite* p. and belongeth to the Wheel, or Pinion 22, which is driven by the fixed Wheel 87.

The hollow Arbor G. carrieth round the *Second-Satellite* S. and belongeth to the Wheel 32 which is driven by the wheel 63. And the like of the *Arbors* F. and E.

Within all theſe hollow Arbors is another fixed one included, on the top of which is a Ball (I) repreſenting the Planet *Jupiter*: round which the *Satellites* move, repreſented by the little Balls p. ſ. t. q. This

This *Satellite-Instrument* may be added to a Watch, by causing the Great-wheel or Dial-wheel to drive round the Arbor K. L. once in 7 days. To do which there are sufficient directions given in the preceding Book.

### *The use of the foregoing Instrument.*

This *Satellite-Instrument* may be of good use both at Sea and Land to assist in finding the longitude by *Jupiter*'s *Satellites*: partly, by giving notice when an approaching Eclipse is, that we may be ready with a *Telescope* to observe it; and partly, when any Eclipse happeneth, to shew which *Satellite* it is that is eclipsed, which is difficult to be seen in the Heavens: and partly, to supply the place of Tables, or Calculation of the *Satellite*-Eclipses, which it may do for a little while, but it must not long be trusted unto.

It may seem foreign to my subject, to shew how the *Longitude* may be found by *Jupiter*'s *Satellites*: but because I would with all my power advance this way (which far transcends all others yet known, especially that of the Log-line) therefore I hope the Reader will excuse this Digression.

The way to find the *Longitude*, by an Eclipse of any of *Jupiter*'s four *Satel-*

*lites*

*lites* is briefly this: knowing by Tables of the Satellite-Eclipses (suppose such as Mr *Flamsteed* published in the *Philos. Transact.* No 177, and afterwards gave *Parker* leave to publish in his *Almanacks*, knowing I say) the time when an Eclipse happeneth in any one part of the World; observe by a *Telescope*, at what time the same Eclipse happeneth in any other part of the World, the difference of time giveth the difference of *Meridians*. Thus a total Immersion of the first Satellite was observed at *Rome*, at 10 h. 07′ 53′ p.m. Which Mr *Flamsteed* notes at 9 h. 15′ 41′. The difference is 52′ 12″; and consequently, *Rome* is 52′ 12″, or 13 deg. 03′ distant from the Meridian of the *English Observatory*, where Mr *Flamsteed* observ'd it.

*Philos. Trans. Dec.* 1685. *No.* 117.

I once had thoughts of shewing the way to calculate the Eclipses of *Jupiter's Satellites*, and to make Tables thereof, by the help of my very good Friend Mr *Flamsteed's*, and some other observations: but considering that it would be too great a digression, and especially that Monsieur *Cassini* hath very ingeniously, and well done it for the *First*, I shall therefore refer the Reader to his Tables, reduced to the *Meridian* and *Style* of *London*, by that very judicious Mathematician Mr *Halley*, in *Philos. Trans.* No 214.

The Reader, I hope will pardon me, if (before I leave this digreſſion) I obſerve a few things which may be of uſe, not only in the Calculation of the Eclipſes of the 3 outermoſt Satellites, but alſo may contract the labour of Calculation in the firſt.

The firſt thing to be obſerved is *Jupiter*'s place. For if he be on his *Aphelion*, he moves floweſt, and conſequently the *Satellites* make their returns to him ſomewhat ſooner, than when he is on his *Mean diſtance* and *Perihelion*. By Mr *Flamſteed*'s firſt Tables the firſt Satellite makes 13 revolutions to *Jupiter*, when he is on his

| | days | h. | ′ | ″ |
|---|---|---|---|---|
| *Aphelion* in ——— | 23 | 00 | 10 | 30 |
| *Mean diſtance* ——— | 23 | 00 | 11 | 48 |
| *Perihelion* ——— | 23 | 00 | 13 | 08 |

The *Second Satellite* makes 10 Revolutions when *Jupiter* is on his

| | days | h. | ′ | ″ |
|---|---|---|---|---|
| *Aphelion* in ——— | 35 | 12 | 55 | 10 |
| *Mean diſtance* ——— | 35 | 12 | 59 | 00 |
| *Perehelion* ——— | 35 | 13 | 03 | 15 |

The *Third Satellite* makes 5 Revolutions when *Jupiter* is on his

| | days | h. | ′ | ″ |
|---|---|---|---|---|
| *Aphelion* in ——— | 35 | 19 | 50 | 15 |
| *Mean-diſtance* ——— | 35 | 19 | 58 | 00 |
| *Perihelion* ——— | 35 | 20 | 06 | 42 |

The

The *Fourth*, or furthermost *Satellite* makes 5 Revolutions to *Jupiter* in his

| | days | h. | ' | '' |
|---|---|---|---|---|
| *Aphelion* in —— | 82 | 17 | 42 | 55 |
| *Mean-distance* —— | 83 | 18 | 25 | 15 |
| *Perihelion* —— | 82 | 19 | 12 | 57 |

From this account it is easy to compute in what time one Revolution of any Satellite is at any time performed: which is the next thing to be observed. Thus in *Jupiter's Mean-distance* the Revolution of the

| | days | h. | ' | '' |
|---|---|---|---|---|
| *First Satellite* is —— | 1 | 18 | 28 | 36 |
| *Second* —— | 3 | 13 | 17 | 54 |
| *Third* —— | 7 | 3 | 59 | 36 |
| *Fourth* —— | 16 | 18 | 05 | 03 |

The Reader may himself, from what hath been said, compute the Periods of the *Satellites* in *Jupiter's* other places.

From these things laid down, it is easy from an Eclipse known, to find the next that will follow. For if you add one, or more Revolutions, you have the Eclipses following. Thus for example, *July* 12 this year 1700, according to Mr *Flamsteed's* computation, the first Satellite comes out of *Jupiter's* shadow

| | days | h. | ' | '' |
|---|---|---|---|---|
| *July* | 12 | 14 | 18 | 00 |
| 1 Revol. | 1 | 18 | 28 | 36 |
| *July* | 14 | 8 | 46 | 36 |
| 4 Revol. | 7 | 1 | 54 | 24 |
| *July* | 21 | 10 | 41 | 00 |

ſhadow at 14 h. 18′ p. m. (according to Mr *Caſſini's* at 14 h. 20′ 56″ p m.) conſequently the next Emerſion is on *Jul.* 14th paſt 8 of Clock in the evening. If you add 4 Revolutions, another Emerſion is on *Jul.* 21 at 10 h. 41′ nearly *p. m.* as here is exemplified in the Margin.

The laſt thing I ſhall take notice of concerning the Satellite Eclipſes is their Durations. This varies according as *Jupiter* is nearer unto, or remoter from the 10th degree of ♒ or ♌ (as Mr *Flamſteed* ſays.) About which points are the *Nodes*, or interſections of the plane of the *Satellite Orbit* and *Jupiter's*, or the *Jovial Ecliptick.* Mr *Caſſini* makes it in 15° of ♒ or ♌, and varies in the length of the Duration of the Eclipſes. But according to Mr *Flamſteed* (the accuracy of whoſe obſervations is not to be diſtruſted) the *greateſt Semiduration* of the

| | h | ′ | ″ |
|---|---|---|---|
| Firſt Satellite is | 1 | 9 | 28 |
| Second ——— | 1 | 27 | 38 |
| Third ——— | 1 | 48 | 55 |
| Fourth ——— | 2 | 26 | 19 |

But as *Jupiter* removeth from his *Nodes*, the Semidurations diminiſh. And when he is gotten 55 degrees from either of his *Nodes*, the *Fourth Satellite* paſſeth clear of the ſhadow, and falleth

leth not into it again, until he comes within 55 degrees of the oppoſite *Node.*

When *Jupiter* is on the Limit, or 90 degrees from his *Nodes,* the *Leaſt Semi-duration* of the Eclipſe of the

| | h | ' | " |
|---|---|---|---|
| Firſt Satellite is | 1 | 6 | 49 |
| Second ——— | 1 | 18 | 59 |
| Third ——— | 1 | 17 | 33 |

From this account of the Duration of the Satellite Eclipſes, we may, having the Immerſion into *Jupiter*'s ſhadow, compute the Emerſion of any Satellite out of his ſhadow: or contrariwiſe, which will be of uſe to ſee both the beginning and end of any Eclipſe, when viſible; I mean, when not hindered by Clouds, day light, or *Jupiter*'s body. Or if by ſome of theſe means we are hindred from ſeeing the one, we may perhaps hereby ſee the other. Thus (for inſtance) this *Auguſt* 6. 1700. the firſt Satellite immerges at 6 h. 44' *p. m.* which cannot be ſeen, not only by reaſon of day light, but alſo becauſe *Jupiter*'s ſhadow lieth a little to the left of his body; but if you add one whole obſcuration(*viz.*twice 1 h. 9' 18" the emerſion you will find viſible at 9 h 3' according to Mr *Flamſteed*; at 9 h. 4' according to Monſieur *Caſſini*'s Tables. Another inſtance will make all

yet

yet more plain, *Oct.* 19. at 9 h. 50′ *p. m.* the 3d Satellite will emerge; from which ſubſtracting one Obſcuration (*viz.* twice 1 h. 48) you will find the immerſion fall at 6 h. 13′ *p. m.* Which may be ſeen, by reaſon that *Jupiter* is at a good diſtance from his Oppoſition to the Sun, ſo that the ſhade lies ſo far on the left hand, as to admit of ſeeing the 3d and 4th Satellite between *Jupiter*'s body and his ſhade.

I might to theſe have added divers other remarks, particularly concerning the Equation of Light, or the time in which Light paſſeth from the Sun to *Jupiter*, which is at laſt ſettled by that ſagacious Obſerver, ſo often before mentioned, Mr *Flamſteed*. But I muſt forbear, fearing that I have already wearied the Readers patience, and ſhall need his pardon for detaining him ſo long on this ſubject, from ſo ſmall an occaſion, as only a Satellite Inſtrument of Watch-work. But I was willing from a ſmall occaſion, rather than not at all, to ſay ſomething to excite the obſervations and enquiries of others concerning this matter, which may be of vaſt uſe in Navigation, making and correcting Maps of Countries, *&c.* Many of thoſe, to whom this matter would be of greateſt uſe, ſcarce ever heard of it, and others (except Monſieur

*Caſſini*)

*Caſſini*) have been backward in favouring the World with their obſervations neceſſary to Calculation. It is indeed a novel ſubject, and full of difficulties, on which little hath been written, and concerning which the firſt material obſervations, to be relied on, were *Hodierna*'s and Mr *Rook*'s. Thoſe of the former were publiſhed, but not very accurate: thoſe of the latter were more accurate, but not publiſhed, and neither of them are yet 50 years old. But neither Novelty nor Difficulty ought to diſcourage the curious and the diligent; to excite whom is partly the deſign of this digreſſion.

## III.

### *To correct the motion of Royal Pendulums.*

IN Chap. 5. of the preceding Book, I judged it to be a good expedient, to bring a *Pendulum* to vibrate nicely, to add a *Bob* underneath the Pendulum Ball. This I have ſince found to ſucceed ſo much according to expectation, that I think it frivolous to attempt by any of the uſual ways to bring a large ſingle Ball to vibrate to one ſingle Beat, in any conſiderable quantity of Time. But when the Great Ball is brought pretty near its due length, the little Regulating Bob will nicely perform the reſt.

The

The *Great Ball* being of the usual weight and form, to swing Seconds, I would have the *Corrector*, or *Regulating Bob*, to be about 10 ounces *Troy*, to screw up and down beneath the Ball; as is directed in Chap. 5 before.

But after all endeavours of this kind, it must be expected, that the Movement will still be exposed to the influences of the weather, and the alterations caused by foulness.

For the more easy and quick bringing of a Pendulum, that should swing Seconds to its true length, I have composed the following Table, which sheweth the alterations which will be made in 24 hours by screwing up, or letting down the great Ball. If therefore the Ball runs upon a Rule divided into inches, and tenths of an inch, 'tis easy to see how much, or how little the Ball needeth to be altered.

| Pendul. length | | Variation of Vibrat. | | |
|---|---|---|---|---|
| in | ten | Min. | Sec. | |
| 38 | 0 | 22 | 33 | |
| 38 | 1 | 20 | 38 | |
| 38 | 2 | 18 | 43 | |
| 38 | 3 | 16 | 48 | |
| 38 | 4 | 14 | 55 | Faster. |
| 38 | 5 | 13 | 2 | |
| 38 | 6 | 11 | 9 | |
| 38 | 7 | 9 | 16 | |
| 38 | 8 | 7 | 25 | |
| 38 | 9 | 5 | 32 | |
| 39 | 0 | 3 | 42 | |
| 39 | 1 | 1 | 51 | |
| 39 | 2 | 00 | 00 | |
| 39 | 3 | 1 | 50 | |
| 39 | 4 | 3 | 40 | |
| 39 | 5 | 5 | 29 | Slower. |
| 39 | 6 | 7 | 19 | |
| 39 | 7 | 9 | 7 | |
| 39 | 8 | 10 | 57 | |
| 39 | 9 | 12 | 42 | |
| 40 | 0 | 14 | 29 | |

This Table will need little explication. If your Ball ſhould be at 39 inches 2 tenths, it would ſwing Seconds. If you alter it to 39 inches, 1 tenth, it would go 1' 51" faſter: if to 39 inches 3 tenths, it would go 1' 51" ſlower. And ſo of the reſt of the Table.

Of

## IV.

### *Of the Equation of Natural Days.*

BY reaſon that the Sun's motion in his Orbit is not equal, and that although he moved equal arches of the *Ecliptick* in equal times, yet he would come to the Meridian with unequal arches of the *Equator*, by whoſe equal Revolutions the *Equal Time* is meaſured; hence (I ſay) it will happen, that altho a Clock ſhould go ſo exactly, as at the years end to agree with the Sun, yet it will vary from the times ſhewed by the exacteſt Sun-Dials. The quantity of which Variations may be ſeen in the following Tables for every day in the year. For which Tables I am greatly obliged to that moſt accurate Aſtronomer Mr *Flamſteed* ſo often mentioned.

Theſe Tables need but little explication. If you would keep your Watch to the *Middle* or *Equal motion* of the Sun, it muſt go ſo many minutes and ſeconds faſter or ſlower than the Sun-Dial, as the Tables ſhew. But if you would keep your Watch to go by the Sun-Dial, you may conclude it goes well, if it loſeth or gaineth every day, ſo many Seconds as you will find in the Table. Thus (for example) *Jan.* 1. in *Leap year*, the Watch ought to be 8 min. 47 Sec. faſter than the

where

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# Mr *Flamsteed*'s Tables of

## The *Bissextile*,

| | *Jan.* | | *Febr.* | | *Marc* | | *April.* | | *May.* | | *Jun* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | M. | S. | M. | S | M | S | M | S | M | S | M |
| 1 | 8 | 47 | 14 | 49 | 10 | 00 | 0 | 41 | 4 | 10 | 0 |
| 2 | 9 | 10 | 14 | 48 | 9 | 43 | 0 | 24 | 4 | 11 | 0 |
| 3 | 9 | 32 | 14 | 46 | 9 | 26 | 0 | 8 | 4 | 12 | 0 |
| 4 | 9 | 54 | 14 | 43 | 9 | 9 | 0 | 7 | 4 | 13 | 0 |
| 5 | 10 | 15 | 14 | 40 | 8 | 51 | 0 | 22 | 4 | 12 | 0 * |
| 6 | 10 | 36 | 14 | 36 | 8 | 33 | 0 | 37 | 4 | 11 | 0 * |
| 7 | 10 | 55 | 14 | 31 | 8 | 15 | 0 | 52 | 4 | 10 | 0 |
| 8 | 11 | 14 | 14 | 26 | 7 | 57 | 1 | 6 | 4 | 8 | 0 |
| 9 | 11 | 32 | 14 | 20 | 7 | 39 | 1 | 19 | 4 | 5 | 0 |
| 10 | 11 | 49 | 14 | 13 | 7 | 20 | 1 | 31 | 4 | 2 | 0 |
| 11 | 12 | 5 | 14 | 5 | 7 | 1 | 1 | 44 | 3 | 59 | 1 |
| 12 | 12 | 22 | 13 | 57 | 6 | 43 | 1 | 57 | 3 | 54 | 1 |
| 13 | 12 | 37 | 13 | 48 | 6 | 24 | 2 | 9 | 3 | 50 | 1 |
| 14 | 12 | 51 | 13 | 39 | 6 | 05 | 2 | 19 | 3 | 45 | 1 |
| 15 | 13 | 5 | 13 | 29 | 5 | 46 | 2 | 30 | 3 | 39 | 1 |
| 16 | 13 | 18 | 13 | 18 | 5 | 27 | 2 | 41 | 3 | 33 | 2 |
| 17 | 13 | 30 | 13 | 7 | 5 | 9 | 2 | 51 | 3 | 26 | 2 |
| 18 | 13 | 41 | 12 | 56 | 4 | 50 | 3 | 0 | 3 | 19 | 2 |
| 19 | 13 | 51 | 12 | 44 | 4 | 31 | 3 | 8 | 3 | 11 | 2 |
| 20 | 14 | 0 | 12 | 32 | 4 | 13 | 3 | 16 | 3 | 3 | 2 |
| 21 | 14 | 9 | 12 | 18 | 3 | 54 | 3 | 24 | 2 | 54 | 3 |
| 22 | 14 | 17 | 12 | 5 | 3 | 36 | 3 | 32 | 2 | 46 | 3 |
| 23 | 14 | 24 | 11 | 51 | 3 | 17 | 3 | 39 | 2 | 37 | 3 |
| 24 | 14 | 30 | 11 | 36 | 2 | 59 | 3 | 45 | 2 | 27 | 3 |
| 25 | 14 | 35 | 11 | 21 | 2 | 40 | 3 | 50 | 2 | 17 | 3 |
| 26 | 14 | 39 | 11 | 5 | 2 | 22 | 3 | 54 | 2 | 6 | 4 |
| 27 | 14 | 43 | 10 | 50 | 2 | 5 | 3 | 58 | 1 | 56 | 4 |
| 28 | 14 | 46 | 10 | 34 | 1 | 47 | 4 | 2 | 1 | 45 | 4 |
| 29 | 14 | 47 | 10 | 17 | 1 | 30 | 4 | 5 | 1 | 34 | 4 |
| 30 | 14 | 49 | | | 1 | 13 | 4 | 8 | 1 | 22 | 4 |
| 31 | 14 | 49 | | | 0 | 57 | | | 1 | 11 | |
| | Watch too fast. | | Watch too fast. | | Watch too fast. | | Watch too slow. | | Watch too slow. | | Watch too fast. |

## of *Æquation* of *Natural-Days.*

### *tile,* or *Leap-year.*

| *June.* M | S | *July.* M | S | *Aug.* M | S | *Sept.* M | S | *Oct.* M | S | *Nov.* M | S | *Dec.* M | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 59 | 4 | 47 | 4 | 26 | 3 | 58 | 13 | 22 | 15 | 19 | 5 | 28 |
| 0 | 47 | 4 | 55 | 4 | 16 | 4 | 19 | 13 | 36 | 15 | 10 | 4 | 59 |
| 0 | 34 | 5 | 2 | 4 | 5 | 4 | 39 | 13 | 49 | 15 | 01 | 4 too | 31 |
| 0 | 22 | 5 | 9 | 3 | 54 | 5 | 00 | 14 | 2 | 14 | 50 | 4 | 2 |
| 0 * | 10 | 5 | 15 | 3 | 43 | 5 | 20 | 14 | 14 | 14 | 38 | 3 | 33 |
| 0 * | 03 | 5 | 20 | 3 | 31 | 5 | 41 | 14 | 25 | 14 | 26 | 3 | 3 |
| 0 | 16 | 5 | 25 | 3 Watch | 18 | 6 | 1 | 14 | 37 | 14 | 13 | 2 slow. | 33 |
| 0 | 29 | 5 | 30 | 3 | 5 | 6 | 22 | 14 | 47 | 14 | 00 | 2 | 3 |
| 0 | 42 | 5 | 34 | 2 | 52 | 6 | 43 | 14 | 57 | 13 | 45 | 1 | 33 |
| 0 | 55 | 5 | 37 | 2 | 38 | 7 | 3 | 15 | 6 | 13 | 30 | 1 | 4 |
| 1 | 7 | 5 | 40 | 2 | 24 | 7 | 24 | 15 | 15 | 13 | 13 | 0 | 34 |
| 1 Watch | 20 | 5 Watch. | 43 | 2 too | 9 | 7 Watch | 44 | 15 Watch | 24 | 12 Watch | 56 | 0 *\|* | 4 |
| 1 | 33 | 5 | 45 | 1 | 54 | 8 | 4 | 15 | 30 | 12 | 38 | 0 | 26 |
| 1 | 45 | 5 | 45 | 1 | 38 | 8 | 24 | 15 | 36 | 12 | 19 | 0 | 56 |
| 1 | 59 | 5 | 46 | 1 | 22 | 8 | 43 | 15 | 42 | 12 | 00 | 1 | 26 |
| 2 | 11 | 5 | 46 | 1 | 5 | 9 | 3 | 15 | 47 | 11 | 40 | 1 | 56 |
| 2 | 23 | 5 | 45 | 0 fast. | 43 | 9 | 23 | 15 | 51 | 11 | 20 | 2 Watch. | 25 |
| 2 too | 35 | 5 too | 44 | 0 | 31 | 9 too | 42 | 15 too | 54 | 10 too | 59 | 2 | 34 |
| 2 | 47 | 5 | 42 | 0 * | 13 | 10 | 2 | 15 | 57 | 10 | 37 | 3 | 23 |
| 2 | 59 | 5 | 40 | 0 * | 5 | 10 | 21 | 15 | 59 | 10 | 14 | 3 | 52 |
| 3 | 10 | 5 | 37 | 0 | 22 | 10 | 39 | 16 | 00 | 9 | 50 | 4 | 21 |
| 3 fast. | 22 | 5 fast. | 33 | 0 too | 40 | 10 slow. | 57 | 16 slow. | 01 | 9 slow. | 26 | 4 too | 40 |
| 3 | 33 | 5 | 29 | 0 | 59 | 11 | 15 | 16 | 00 | 9 | 2 | 5 | 16 |
| 3 | 44 | 5 | 25 | 1 | 19 | 11 | 32 | 15 | 59 | 8 | 37 | 5 | 43 |
| 3 | 54 | 5 | 19 | 1 | 39 | 11 | 4 | 15 | 57 | 8 | 11 | 6 | 11 |
| 4 | 4 | 5 | 13 | 1 | 58 | 12 | 6 | 15 | 54 | 7 | 45 | 6 | 37 |
| 4 | 13 | 5 | 07 | 2 slow. | 17 | 12 | 22 | 15 | 50 | 7 | 19 | 7 fast. | 3 |
| 4 | 22 | 5 | 0 | 2 | 37 | 12 | 37 | 15 | 46 | 6 | 52 | 7 | 29 |
| 4 | 31 | 4 | 52 | 2 | 57 | 12 | 52 | 15 | 40 | 6 | 24 | 7 | 54 |
| 4 | 39 | 4 | 44 | 3 | 18 | 13 | 8 | 15 | 34 | 5 | 57 | 8 | 18 |
| | | 4 | 35 | 3 | 38 | | | 15 | 27 | | | 8 | 41 |

# The *First* af

| | Jan. | | Febr. | | Marc. | | April. | | May | | June. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | S | M | S | M | S | M | S | M | S | M |
| 1 | 9 | 4 | 14 | 48 | 10 | 4 | 0 | 4[illegible] | 4 | 10 | 1 |
| 2 | 9 | 26 | 14 | 46 | 9 | 47 | 0 | 28 | 4 | 1[illegible] | 0 |
| 3 | 9 | 48 | 14 | 44 | 9 | 30 | 0 | 12 | 4 | 12 | 0 |
| 4 | 10 | 10 | 14 | 41 | 9 | 13 | 0 | | 4 | 13 | 0 |
| 5 | 10 | 31 | 14 | 37 | 8 | [illegible] | 0 | [illegible] | 4 | [illegible]2 | 0 |
| 6 | 10 | 50 | 14 | 32 | 8 | 37 | 0 | 3[illegible] | 4 | 11 | 0 |
| 7 | 11 | 9 | 14 | 27 | 8 | 19 | 0 | 4[illegible] | 4 | 10 | 0 |
| 8 | 11 | 2 | 14 | 21 | 8 | | 1 | | 4 | 8 | 0 |
| 9 | 11 | 4 | 14 | 15 | 7 | 43 | 1 | 1[illegible] | 4 | 6 | 0 |
| 10 | 12 | 2 | 14 | 7 | 7 | 2 | 1 | [illegible] | 4 | 3 | 0 |
| 11 | 12 | 18 | 13 | 59 | 7 | 6 | 1 | 4 | 4 | [illegible] | 1 |
| 12 | 12 | 34 | 13 | 50 | 6 | 47 | 1 | 5 | 3 | 56 | 1 |
| 13 | 12 | Watch. 47 | 13 | Watch 41 | 6 | Watch 28 | 2 | Watch | 3 | Watch 51 | 1 Watch |
| 14 | 13 | 2 | 13 | 31 | 6 | 10 | 2 | 1 | 3 | 46 | 1 |
| 15 | 13 | 15 | 13 | 21 | 5 | 51 | 2 | 2 | 3 | 40 | 1 |
| 16 | 13 | 27 | 13 | 10 | 5 | 32 | 2 | 38 | 3 | 4 | 2 |
| 17 | 13 | 38 | 12 | 59 | 5 | 14 | 2 | 48 | 3 | 8 | 2 |
| 18 | 13 | too 48 | 12 | too 47 | 4 | too 55 | 2 | too 57 | 3 | too 21 | 2 too |
| 19 | 13 | 58 | 12 | 35 | 4 | 36 | 3 | [illegible] | 3 | 13 | 2 |
| 20 | 14 | 7 | 12 | 22 | 4 | 17 | 3 | 14 | 3 | 5 | 2 |
| 21 | 14 | 15 | 12 | 8 | 3 | 5[illegible] | 3 | 22 | 2 | 56 | 3 |
| 22 | 14 | 22 | 11 | 54 | 3 | 42 | 3 | 30 | 2 | 48 | 3 |
| 23 | 14 | fast. 28 | 11 | fast. 40 | 3 | fast. 22 | 3 | slow. 37 | 2 | slow. 39 | 3 fast. |
| 24 | 14 | 34 | 11 | 24 | 3 | 3 | 3 | 43 | 2 | 28 | 3 |
| 25 | 14 | 3[illegible] | 11 | 9 | 2 | 45 | 3 | 49 | 2 | 19 | 3 |
| 26 | 14 | 4[illegible] | 10 | 54 | 2 | 2[illegible] | 3 | 53 | 2 | 9 | 4 |
| 27 | 14 | 4[illegible] | 10 | 38 | 2 | 9 | 3 | 57 | 1 | 59 | 4 |
| 28 | 14 | 47 | 10 | 21 | 1 | 51 | 4 | 1 | 1 | 48 | 4 |
| 29 | 14 | 48 | | | 1 | 34 | 4 | 4 | 1 | 37 | 4 |
| 30 | 14 | 49 | | | 1 | 17 | 4 | 7 | 1 | 25 | 4 |
| 31 | 14 | 49 | | | 1 | 1 | | | 1 | 14 | |

*Place these Tables in the Ap*

after *Leap-year.*

| *June.* M | S | *July.* M | S | *Aug.* M | S | *Sept.* M | S | *Octob.* M | S | *Nov.* M | S | *Dec.* M | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 4 | 45 | 4 | 2 | 3 | 53 | 13 | 18 | 15 | 21 | 5 | 35 |
| 0 | 50 | 4 | 53 | 4 Watch | 18 | 4 | 14 | 13 | 32 | 15 | 13 | 5 | 6 |
| 0 | 37 | 5 | 0 | 4 | 8 | 4 | 34 | 13 | 46 | 15 | 3 | 4 too | 38 |
| 0 | 25 | 5 | 7 | 3 | 57 | 4 | 55 | 13 | 59 | 14 | 53 | 4 | 9 |
| 0 * | 13 | 5 | 13 | 3 | 46 | 5 | 15 | 14 | 11 | 14 | 41 | 3 | 40 |
| 0 | 0 | 5 | 18 | 3 | 34 | 5 | 36 | 14 | 23 | 13 | 29 | 3 | 10 |
| 0 | 13 | 5 | 24 | 3 too | 21 | 5 | 56 | 14 | 34 | 14 | 17 | 2 slow. | 40 |
| 0 | 26 | 5 | 29 | 3 | 8 | 6 | 17 | 14 | 44 | 14 | 3 | 2 | 10 |
| 0 | 39 | 5 | 33 | 2 | 55 | 6 | 38 | 14 | 54 | 13 | 49 | 1 | 40 |
| 0 | 52 | 5 | 36 | 2 | 41 | 6 | 58 | 15 | 4 | 13 | 34 | 1 | 11 |
| 1 | 4 | 5 | 39 | 2 | 27 | 7 | 19 | 15 | 13 | 13 | 17 | 0 | 41 |
| 1 Watch | 17 | 5 Watch | 42 | 2 | 13 | 7 Watch | 39 | 15 Watch | 22 | 13 Watch | 0 | 0 *\|* | 11 |
| 1 | 30 | 5 | 44 | 1 fast. | 58 | 7 | 59 | 15 | 28 | 12 | 43 | 0 | 19 |
| 1 | 43 | 5 | 45 | 1 | 42 | 8 | 19 | 15 | 34 | 12 | 24 | 0 | 49 |
| 1 | 56 | 5 | 46 | 1 | 26 | 8 | 38 | 15 | 40 | 12 | 5 | 1 | 19 |
| 2 | 8 | 5 | 46 | 1 | 9 | 8 | 58 | 15 | 45 | 11 | 45 | 1 | 49 |
| 2 | 20 | 5 too | 45 | 0 | 52 | 9 | 18 | 15 | 50 | 11 | 25 | 2 Watch | 18 |
| 2 too | 32 | 5 | 44 | 0 *\|* | 35 | 9 too | 37 | 15 too | 53 | 11 too | 4 | 2 | 47 |
| 2 | 44 | 5 | 42 | 0 | 17 | 9 | 57 | 15 | 56 | 10 | 42 | 3 | 16 |
| 2 | 56 | 5 | 40 | 0 | 1 | 10 | 16 | 15 | 58 | 10 | 20 | 3 | 45 |
| 3 | 7 | 5 | 38 | 0 | 18 | 10 | 3 | 15 | 59 | 9 | 56 | 4 | 14 |
| 3 fast. | 19 | 5 ft. | 34 | 0 too | 36 | 10 slow. | 52 | 16 slow. | 1 | 9 slow. | 32 | 4 too. | 42 |
| 3 | 30 | 5 | 30 | 0 | 55 | 11 | 10 | 16 | 0 | 9 | 8 | 5 | 9 |
| 3 | 41 | 5 | 26 | 1 | 14 | 11 | 28 | 15 | 59 | 8 | 43 | 5 | 36 |
| 3 | 51 | 5 | 20 | 1 | 34 | 11 | 45 | 15 | 57 | 8 | 17 | 6 | 4 |
| 4 | 1 | 5 | 14 | 1 | 53 | 12 | 2 | 15 | 55 | 7 | 51 | 6 | 30 |
| 4 | 11 | 5 | 8 | 2 slow. | 12 | 12 | 18 | 15 | 51 | 7 | 25 | 6 fast. | 57 |
| 4 | 20 | 5 | 2 | 2 | 32 | 12 | 33 | 15 | 47 | 6 | 59 | 7 | 33 |
| 4 | 29 | 4 | 54 | 2 | 52 | 12 | 49 | 15 | 41 | 6 | 31 | 7 | 48 |
| 4 | 37 | 4 | 46 | 3 | 13 | 13 | 4 | 15 | 35 | 6 | 3 | 8 | 12 |
| | | 4 | 37 | 3 | 33 | | | 15 | 29 | | | 8 | 35 |

*Appendix between* Page 18 *and* 19.

The *Second* after L

| | *Jan.* | | *Feb.* | | *Mar* | | *April* | | *May.* | | *June.* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | S | M | S | M | S | M | S | M | S | M | S |
| 1 | 8 | 59 | 14 | 48 | 10 | 8 | 0 | 49 | 4 | 9 | 1 | 5 |
| 2 | 9 | 21 | 14 | 47 | 9 | 5 | 0 | 32 | 4 | 11 | 0 | 53 |
| 3 | 9 | 43 | 14 | 45 | 9 | 3[illegible] | 0 * | 16 | 4 | 12 | 0 | 40 |
| 4 | 10 | 5 | 14 | 42 | 9 | 17 | 0 1 * | 1 | 4 | 13 | 0 | 28 |
| 5 | 10 | 26 | 14 | 38 | 8 | [illegible] | 0 | 14 | 4 | 12 | 0 | 16 |
| 6 | 10 | 45 | 14 | 33 | 8 | 4[illegible] | 0 | 29 | 4 | 11 | 0 * | 3 |
| 7 | 11 | 4 | 14 | 28 | 8 | 24 | 0 | 44 | 4 | 10 | 0 1 * | 10 |
| 8 | 11 Watch | 23 | 14 Watch | 23 | 8 Watch | [illegible] | 0 Watch | 58 | 4 Watch | 8 | 0 | 23 |
| 9 | 11 | 40 | 14 | 14 | 7 | 47 | 1 | 12 | 4 | 6 | 0 | 36 |
| 10 | 11 | 57 | 14 | 9 | 7 | 2[illegible] | 1 | 26 | 4 | 4 | 0 | 49 |
| 11 | 12 | 14 | 14 | 1 | 7 | 10 | 1 | 38 | 4 | 1 | 1 | 1 |
| 12 | 12 | 30 | 13 | 52 | 6 | 52 | 1 | 51 | 3 | 57 | 1 | 14 |
| 13 | 12 too | 44 | 13 too | 43 | 6 too | 33 | 2 too | 3 | 3 too | 52 | 1 Watch | 27 |
| 14 | 12 | 58 | 13 | 34 | 6 | 15 | 2 | 14 | 3 | 47 | 1 | 40 |
| 15 | 13 | 12 | 13 | 24 | 5 | 56 | 2 | 24 | 3 | 41 | 1 | 53 |
| 16 | 13 | 24 | 13 | 13 | 5 | 37 | 2 | 35 | 3 | 35 | 2 | 5 |
| 17 | 13 | 35 | 13 | 2 | 5 | 18 | 2 | 46 | 3 | 29 | 2 | 17 |
| 18 | 13 fast. | 46 | 12 fast. | 50 | 5 fast. | 0 | 2 slow. | 56 | 3 slow | 23 | 2 too | 29 |
| 19 | 13 | 56 | 12 | 37 | 4 | 41 | 3 | 4 | 3 | 15 | 2 | 41 |
| 20 | 14 | 5 | 12 | 25 | 4 | 22 | 3 | 12 | 3 | 7 | 2 | 53 |
| 21 | 14 | 13 | 12 | 12 | 4 | 3 | 3 | 20 | 2 | 58 | 3 | 4 |
| 22 | 14 | 20 | 11 | 57 | 3 | 44 | 3 | 28 | 2 | 50 | 3 | 16 |
| 23 | 14 | 27 | 11 | 43 | 3 | 26 | 3 | 35 | 2 | 41 | 3 fast. | 27 |
| 24 | 14 | 32 | 11 | 28 | 3 | 8 | 3 | 42 | 2 | 31 | 3 | 38 |
| 25 | 14 | 37 | 11 | 13 | 2 | 49 | 3 | 47 | 2 | 21 | 3 | 48 |
| 26 | 14 | 41 | 10 | 58 | 2 | 31 | 3 | 52 | 2 | 11 | 3 | 59 |
| 27 | 14 | 44 | 10 | 42 | 2 | 13 | 3 | 56 | 2 | 1 | 4 | 9 |
| 28 | 14 | 47 | 10 | 25 | 1 | 55 | 4 | 0 | 1 | 51 | 4 | 18 |
| 29 | 14 | 48 | | | 1 | 38 | 4 | 3 | 1 | 40 | 4 | 27 |
| 30 | 14 | 49 | | | 1 | 22 | 4 | 6 | 1 | 28 | 4 | 35 |
| 31 | 14 | 49 | | | 1 | 5 | | | 1 | 17 | | |

r *Leap-year.*

| e. | *July.* | | | *Aug.* | | | *Sept.* | | | *Octob.* | | | *Nov.* | | | *Dec.* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | M | | S | M | | S | M | | S | M | | S | M | | S | M | | S |
| 5 | 4 | | 43 | 4 | | 30 | 3 | | 48 | 13 | | 14 | 15 | | 23 | 5 | | 42 |
| 53 | 4 | | 51 | 4 | | 20 | 4 | | 9 | 13 | | 28 | 15 | | 15 | 5 | | 13 |
| 40 | 4 | | 58 | 4 | | 10 | 4 | | 29 | 13 | | 42 | 15 | | 5 | 4 | too | 45 |
| 28 | 5 | | 5 | 4 | | 0 | 4 | | 50 | 13 | | 56 | 14 | | 55 | 4 | | 16 |
| 16 | 5 | | 11 | 3 | | 49 | 5 | | 10 | 14 | | 8 | 14 | | 44 | 3 | | 47 |
| 3 | 5 | | 17 | 3 | | 37 | 5 | | 31 | 14 | | 20 | 14 | | 32 | 3 | | 17 |
| 10 | 5 | | 23 | 3 | | 24 | 5 | | 51 | 14 | | 31 | 14 | | 20 | 2 | | 47 |
| 23 | 5 | Watch | 28 | 3 | Watch | 11 | 6 | Watch | 12 | 14 | Watch | 41 | 14 | Watch | 6 | 2 | slow. | 17 |
| 36 | 5 | | 32 | 2 | | 58 | 6 | | 33 | 14 | | 51 | 13 | | 52 | 1 | | 47 |
| 49 | 5 | | 35 | 2 | | 44 | 6 | | 53 | 15 | | 1 | 13 | | 38 | 1 | | 18 |
| 1 | 5 | | 38 | 2 | | 30 | 7 | | 14 | 15 | | 11 | 13 | | 21 | 0 | | 48 |
| 14 | 5 | | 41 | 2 | | 16 | 7 | | 34 | 15 | | 20 | 13 | | 4 | 0 | | 18 |
| 27 | 5 | too | 43 | 2 | too | 2 | 7 | too | 54 | 15 | too | 26 | 12 | too | 47 | 0 | *l* | 12 |
| 40 | 5 | | 45 | 1 | | 46 | 8 | | 14 | 15 | | 32 | 12 | | 28 | 0 | | 42 |
| 53 | 5 | | 46 | 1 | | 30 | 8 | | 33 | 15 | | 38 | 12 | | 9 | 1 | | 12 |
| 5 | 5 | | 46 | 1 | | 13 | 8 | | 53 | 15 | | 44 | 11 | | 50 | 1 | | 42 |
| 17 | 5 | | 45 | 0 | | 56 | 9 | | 13 | 15 | | 49 | 11 | | 30 | 2 | | 11 |
| 29 | 5 | fast. | 44 | 0 | fast. | 39 | 9 | slow. | 32 | 15 | slow. | 52 | 11 | slow. | 9 | 2 | Watch | 40 |
| 41 | 5 | | 42 | 0 | | 21 | 9 | | 52 | 15 | | 55 | 10 | | 47 | 3 | | 9 |
| 53 | 5 | | 40 | 0 | | 3 | 10 | | 11 | 15 | | 57 | 10 | | 25 | 3 | | 38 |
| 4 | 5 | | 38 | 0 | | 14 | 10 | | 30 | 15 | | 59 | 10 | | 2 | 4 | | 7 |
| 16 | 5 | | 35 | 0 | | 31 | 10 | | 48 | 16 | | 1 | 9 | | 38 | 4 | | 35 |
| 27 | 5 | | 31 | 0 | too | 50 | 11 | | 6 | 16 | | 0 | 9 | | 14 | 5 | too | 2 |
| 38 | 5 | | 27 | 1 | | 9 | 11 | | 24 | 15 | | 59 | 8 | | 49 | 5 | | 29 |
| 48 | 5 | | 22 | 1 | | 29 | 11 | | 41 | 15 | | 57 | 8 | | 23 | 5 | | 57 |
| 59 | 5 | | 16 | 1 | | 49 | 11 | | 58 | 15 | | 55 | 7 | | 57 | 6 | | 23 |
| 9 | 5 | | 10 | 2 | | 7 | 12 | | 14 | 15 | | 52 | 7 | | 31 | 6 | | 50 |
| 18 | 5 | | 3 | 2 | slow. | 27 | 12 | | 29 | 15 | | 48 | 7 | | 5 | 7 | fast. | 16 |
| 27 | 4 | | 56 | 2 | | 47 | 12 | | 45 | 15 | | 43 | 6 | | 38 | 7 | | 41 |
| 35 | 4 | | 48 | 3 | | 8 | 13 | | 0 | 15 | | 37 | 6 | | 10 | 8 | | 6 |
| | 4 | | 39 | 3 | | 28 | | | | 15 | | 31 | | | | 8 | | 29 |

The *Third* afte

| M D | *Jan.* M | *Jan.* S | *Feb.* M | *Feb.* S | *Marc.* M | *Marc.* S | *April.* M | *April.* S | *May* M | *May* S | *June.* M | *June.* S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 53 | 14 | 49 | 10 | 12 | 0 | 53 | 4 | 9 | 1 | |
| 2 | 9 | 15 | 14 | 47 | 9 | 54 | 0 | 36 | 4 | 10 | 0 | 5 |
| 3 | 9 | 37 | 14 | 45 | 9 | 38 | 0 | 20 | 4 | 12 | 0 | 4 |
| 4 | 9 | 59 | 14 | 42 | 9 | 21 | 0 *\|* | 4 | 4 | 13 | 0 | 3 |
| 5 | 10 | 20 | 14 | 39 | 9 | 4 | 0 | 11 | 4 | 12 | 0 | 1 |
| 6 | 10 | 41 | 14 | 34 | 8 | 46 | 0 | 26 | 4 | 12 | 0 *\|* | |
| 7 | 11 | 00 | 14 | 29 | 8 | 28 | 0 | 41 | 4 | 11 | 0 | |
| 8 | 11 Watch | 18 | 14 Watch | 24 | 8 Watch | 10 | 0 Watch | 55 | 4 Watth | 9 | 0 | 2 |
| 9 | 11 | 36 | 14 | 18 | 7 | 52 | 1 | 9 | 4 | 7 | 0 | 3 |
| 10 | 11 | 54 | 14 | 11 | 7 | 34 | 1 | 22 | 4 | 4 | 0 | 4 |
| 11 | 12 | 10 | 14 | 3 | 7 | 15 | 1 | 35 | 4 | 1 | 0 | 5 |
| 12 | 11 | 26 | 13 | 54 | 6 | 56 | 1 | 48 | 3 | 58 | 1 | 1 |
| 13 | 12 too | 41 | 13 too | 45 | 6 too | 38 | 2 too | 0 | 3 too | 53 | 1 Watch | 2 |
| 14 | 12 | 55 | 13 | 36 | 6 | 19 | 2 | 11 | 3 | 48 | 1 | |
| 15 | 13 | 9 | 13 | 26 | 6 | 0 | 2 | 22 | 3 | 43 | 1 | 3 |
| 16 | 13 | 21 | 13 | 15 | 5 | 41 | 2 | 33 | 3 | 37 | 2 | |
| 17 | 13 | 33 | 13 | 4 | 5 | 23 | 2 | 43 | 3 | 31 | 2 | 1 |
| 18 | 13 fast | 43 | 12 fast | 53 | 5 fast. | 4 | 2 flow. | 52 | 3 flow. | 24 | 2 too | 2 |
| 19 | 13 | 53 | 12 | 41 | 4 | 45 | 3 | 1 | 3 | 17 | 2 | 3 |
| 20 | 14 | 03 | 12 | 28 | 4 | 26 | 3 | 10 | 3 | 9 | 2 | 5 |
| 21 | 14 | 11 | 12 | 15 | 4 | 7 | 3 | 18 | 3 | 0 | 3 | |
| 22 | 14 | 18 | 12 | 1 | 3 | 49 | 3 | 26 | 2 | 52 | 3 | 1 |
| 23 | 14 | 25 | 11 | 47 | 3 | 31 | 3 | 33 | 2 | 43 | 3 fast | 2 |
| 24 | 14 | 31 | 11 | 32 | 3 | 13 | 3 | 40 | 2 | 34 | 3 | 3 |
| 25 | 14 | 36 | 11 | 16 | 2 | 54 | 3 | 46 | 2 | 2 | 3 | |
| 26 | 14 | 40 | 11 | 1 | 2 | 31 | 3 | 51 | 2 | 14 | 3 | 5 |
| 27 | 14 | 43 | 10 | 46 | 2 | 17 | 3 | 55 | 2 | 4 | 4 | |
| 28 | 14 | 46 | 10 | 30 | 2 | 0 | 3 | 59 | 1 | 53 | 4 | 1 |
| 29 | 14 | 47 | | | 1 | 42 | 4 | 3 | 1 | 42 | 4 | 2 |
| 30 | 14 | 48 | | | 1 | 25 | 4 | 6 | 1 | 31 | 4 | 3 |
| 31 | 14 | 49 | | | 1 | 9 | | | 1 | 19 | | |

## after Leap year.

| June. | | July. | | Aug. | | Sep. | | Octob. | | Nov. | | Dec. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M | S | M | S | M | S | M | S | M | S | M | S | M | S |
| 1 | 8 | 4 | 41 | 4 | 32 | 3 | 43 | 13 | 11 | 15 | 25 | 5 | 49 |
| 0 | 56 | 4 | 49 | 4 | 23 | 4 | 4 | 13 | 25 | 15 | 17 | 5 | 20 |
| 0 | 43 | 4 | 57 | 4 | 13 | 4 | 24 | 13 | 39 | 15 | 8 | 4 too | 52 |
| 0 | 31 | 5 | 4 | 4 | 2 | 4 | 45 | 13 | 53 | 14 | 58 | 4 | 23 |
| 0 | 19 | 5 | 10 | 3 | 51 | 5 | 5 | 14 | 5 | 14 | 47 | 3 | 54 |
| 0 | 6 | 5 | 13 | 3 | 40 | 5 | 26 | 14 | 17 | 14 | 35 | 3 | 25 |
| 0 *\|* | 7 | 5 Watch | 22 | 3 Watch | 27 | 5 Watch | 46 | 14 Watch | 28 | 14 Watch | 23 | 2 flow. | 55 |
| 0 | 20 | 5 | 27 | 3 | 14 | 6 | 7 | 14 | 39 | 14 | 10 | 2 | 25 |
| 0 | 33 | 5 | 31 | 3 | 01 | 6 | 28 | 14 | 49 | 13 | 50 | 1 | 55 |
| 0 | 46 | 5 | 35 | 2 | 48 | 6 | 48 | 14 | 59 | 13 | 41 | 1 | 25 |
| 0 | 58 | 5 | 38 | 2 | 34 | 7 | 9 | 15 | 9 | 13 | 25 | 0 | 56 |
| 1 Watch | 11 | 5 | 41 | 2 | 20 | 7 | 29 | 15 | 18 | 13 | 8 | 0 *\|* | 26 |
| 1 | 24 | 5 too | 43 | 2 too | 5 | 7 too | 49 | 15 too | 25 | 12 too | 51 | 0 | 4 |
| 1 | 7 | 5 | 45 | 1 | 50 | 8 | 9 | 15 | 31 | 12 | 33 | 0 | 34 |
| 1 | 30 | 5 | 46 | 1 | 34 | 8 | 29 | 15 | 37 | 12 | 14 | 1 | 4 |
| 2 | 2 | 5 | 46 | 1 | 17 | 8 | 48 | 15 | 43 | 11 | 55 | 1 | 34 |
| 2 | 14 | 5 | 45 | 1 fast. | 0 | 9 | 8 | 15 | 48 | 11 | 35 | 2 Watch | 4 |
| 2 too | 26 | 5 fast. | 44 | 0 | 43 | 9 flow. | 28 | 15 flow | 52 | 11 flow. | 14 | 2 | 33 |
| 2 | 38 | 5 | 43 | 0 | 26 | 9 | 47 | 15 | 55 | 10 | 53 | 3 | 2 |
| 2 | 50 | 5 | 41 | 0 * | 9 | 10 | 7 | 15 | 57 | 10 | 31 | 3 | 31 |
| 3 | 2 | 5 | 39 | 0 * | 9 | 10 | 25 | 15 | 59 | 10 | 8 | 4 | 0 |
| 3 | 13 | 5 | 36 | 0 | 27 | 10 | 43 | 16 | 0 | 9 | 44 | 4 | 28 |
| 3 fast | 25 | 5 | 32 | 0 too | 46 | 11 | 1 | 16 | 1 | 9 | 20 | 4 too | 56 |
| 3 | 36 | 5 | 28 | 1 | 5 | 11 | 19 | 16 | 0 | 8 | 55 | 5 | 23 |
| 3 | | 5 | 23 | 1 | 24 | 11 | 37 | 15 | 58 | 8 | 30 | 5 | 50 |
| 3 | 57 | 5 | 17 | 1 | 44 | 11 | 54 | 15 | 56 | 8 | 4 | 6 | 17 |
| 4 | 7 | 5 | 11 | 2 | 3 | 12 | 10 | 15 | 53 | 7 | 38 | 6 | 44 |
| 4 | 16 | 5 | 5 | 2 flow | 22 | 12 | 26 | 15 | 49 | 7 | 12 | 7 fast. | 10 |
| 4 | 25 | 4 | 58 | 2 | 42 | 12 | 41 | 15 | 44 | 6 | 45 | 7 | 36 |
| 4 | 33 | 4 | 50 | 3 | 3 | 12 | 57 | 15 | 38 | 6 | 17 | 8 | 0 |
| | | 4 | 41 | 3 | 23 | | | 15 | 32 | | | 8 | 24 |

the Sun Dial: on *Jan.* 2. it ought to be 9′ 10″, *&c.* If you would know on the ſame days, whether your Watch goes well, when kept to go by the Sun-dyal if ſet on *Jan.* 1. it hath gained on *Jan.* 2. as much as 8′ 47″ wanteth of 9′-10″. *viz.* 23″ you may conclude your Watch goes well. Otherwiſe you muſt ſcrew up, or let down the *Ball* or *Corrector*, until it loſeth, or gaineth according to the Equation Tables.

The Tables will ſerve for many years, being mede for *Biſſextile*, and the 3 years following. By an Almanack therefore, or any other way, knowing the Year, you may find what Table you are to uſe all that year.

By reaſon of the Refractions, or ſome error in the Sun-Dial, it may be convenient to compare, or ſet your Watch at ſome certain hour of the day. Noon is a good time for it, if you have a nice *Meridian-line*, or any way to ſee when the Sun is exactly South, because the time of the Day is not at all then varied by the Refractions, in Dials that caſt a ſhade.

## V.

### *To find a Meridian-Line.*

It may happen that we may be at a Place, where there is no Sun-Dial, or not one to be relied upon; or indeed where

where we have a good one, it may be of great uſe to us to have a *Meridian-Line*: For the finding of which there are divers ways, but I ſhall ſhew only two.

The firſt is, draw one or more Circles on ſome plain, as on the bottom of a Southern Window. (Or you may make the center on the Southern edge of the Window, and draw only half circles.) Hang up a Thread and Plumbet exactly over, or in the center of the Circles. By a Bead or two ſliding up and down the Thread, mark out exactly the points of the Circles, touched by the Shade of the Beads in ſome of the Morning Hours (the longer before Noon the better.) In the afternoon when the ſame ſhade of the Beads toucheth the circles, mark that point, or points alſo. A line drawn thro the Center, and in the middle, between theſe two points in the Circle, is the Meridian-line, or near ſo.

If you can't hang up a Plumbet, a Pin ſet exactly upright will do the matter.

Another, and better way, is by the *Pole ſtar*, when it is exactly upon the Meridian. Or if but near ſo, the error will not be great.

You may find the time when the Pole-ſtar comes to the Meridian, by Subſtracting the Suns Right Aſcention from the

right Aſcention of the Pole-ſtar, and turning the remainder into hours, minutes and ſeconds, allowing to every degree four minutes of time, whereby you will have the Apparent time, when the Pole-ſtar comes on the Meridian above the Pole. I ſcarce need to obſerve, that the time when it comes under the Pole is 12 hours diſtant.

You may ſhorten your labour by uſing Tables of the Sun's right aſcention in Time, which you may find in Sir *J. Moor's Mathem. Compendium.*

*Note*, If the *Sun's* R. Aſcention exceeds the *Pole-ſtars* R. A. you muſt add 24 hours to the Pole-ſtar's R. A. & then ſubſtract. The right aſcention of the Pole-Star is determined by Mr *Flamſteed* $0^h\ 33'.\ 44''$ of time in the year 1690, and the increaſe of its R. Aſcention $1'.\ 16''$ of time in 10 years. Therefore this preſent Year 1700 its true R. Aſcention is $0^h\ 35'.\ 00''$ of time.

If the unlearned Reader ſhould think this way difficult, he may ſee when the *Pole-Star* comes near the Meridian, by hanging up a Line and Plumbet, and obſerving when the firſt Star in the *Great-Bear's* tail, next her Rump, comes under the Line on one ſide of the Pole, or when the Plumb-line interſects the Star in *Caſſiopeia's* Knee on the other ſide of the Pole.

When

When the *Pole-ſtar* is found to be on the Meridian, if you hang up two ſtrings with Plumbets, between the *Pole-Star* and your eye, this will be a *Meridian-line*, to ſee when the Sun comes to the Meridian. Or you may do it with a Crevis between two boards, or plates of Metal, almoſt touching one another. Or (which is a better way) with a pair of Sights, ſuch as Surveyors uſe (but much longer) with a Crevis in one Sight next the eye; and a large aperture in the other with a fine Cats-gut ſtring down the middle. Theſe ſhould be counter-changed, ſo as to look either at the Pole-ſtar by night; or the other way at the Sun by day.

But much the beſt way which I have yet thought of, and which is exceedingly nice, is with the inſtrument, Fig. 3. which is thus made. At each end of a board, or rather ſmall flat Iron-bar (A. B) fix two upright ſights: one with a very ſmall Hole (a. b.) to look through to the Sun; the other (c. d) with a larger hole, to look at the Pole-ſtar. Not far from the Sights, on the ſame bar, fix two arms (C.D, C.D) to bend off, ſo as to be out of the way of the Sights, when you look through them. On the top of theſe arms, place a ſmall rod of Iron or Wood, to turn with a joynt at D. which rod is to bear

ge 22d. Appendix.

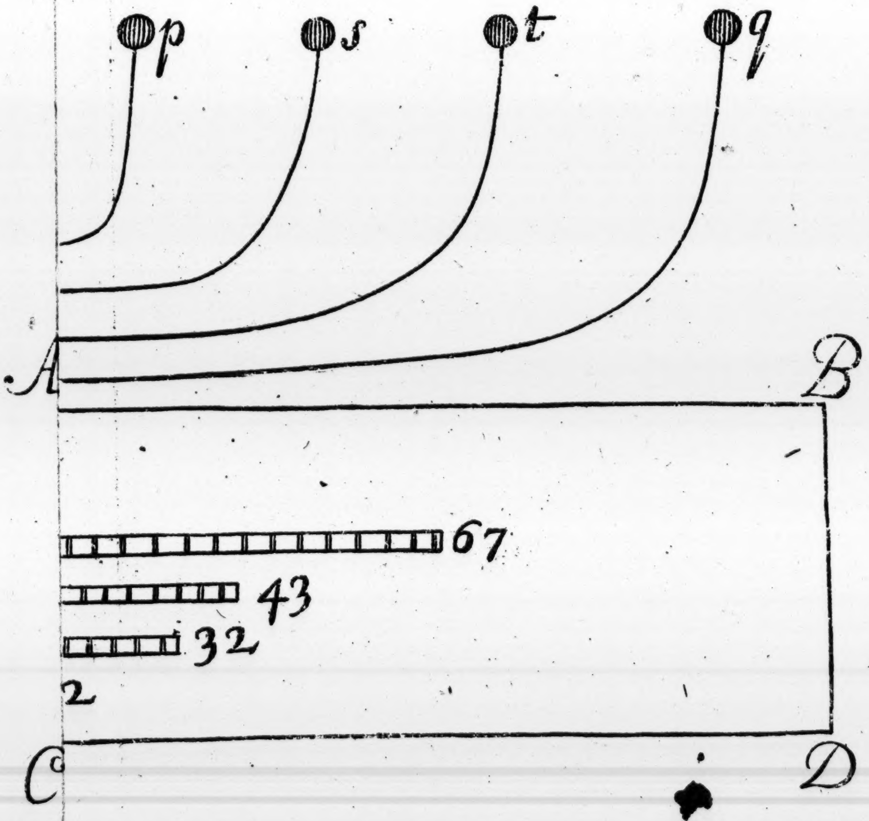


Fig. 3.

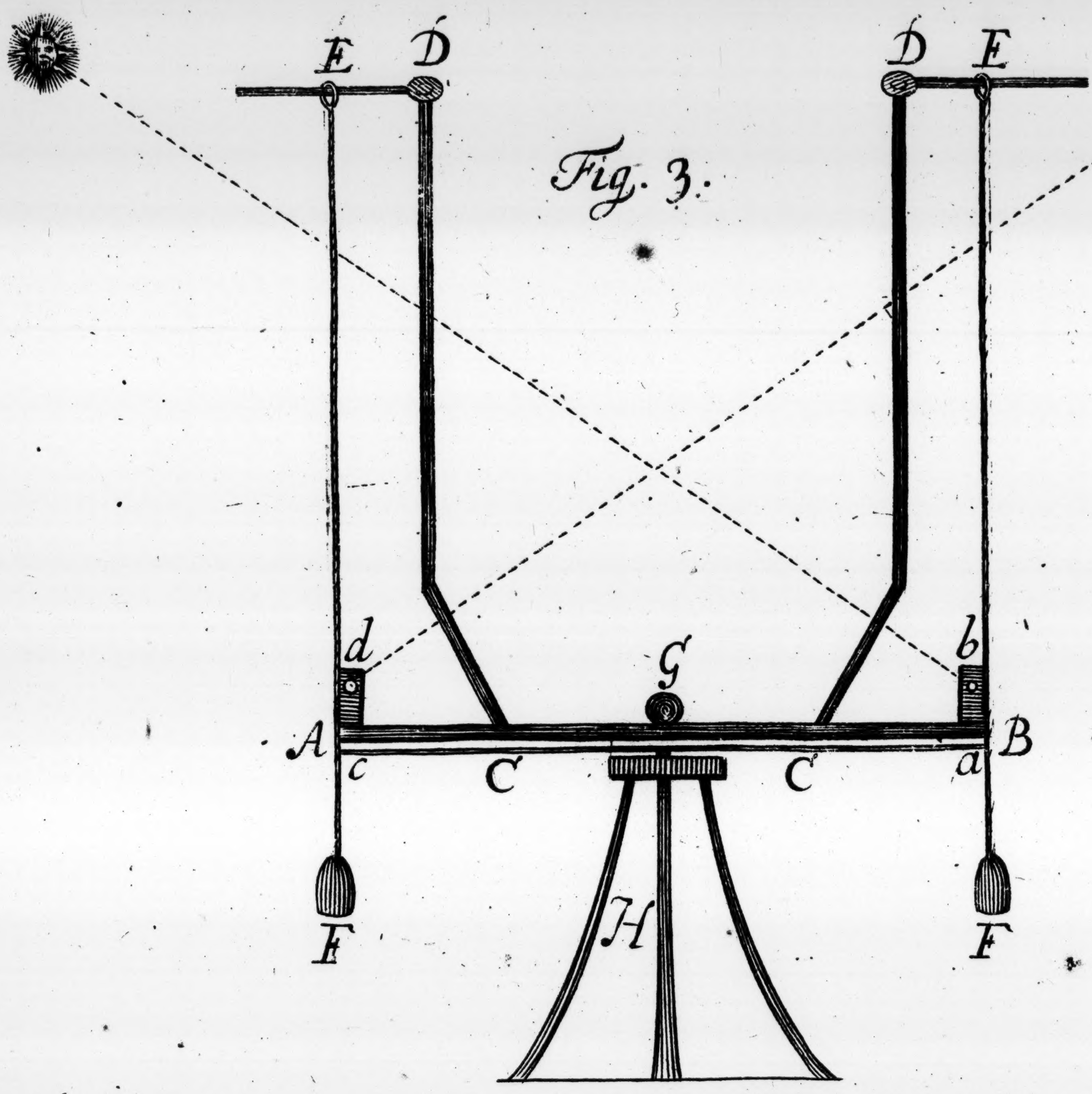
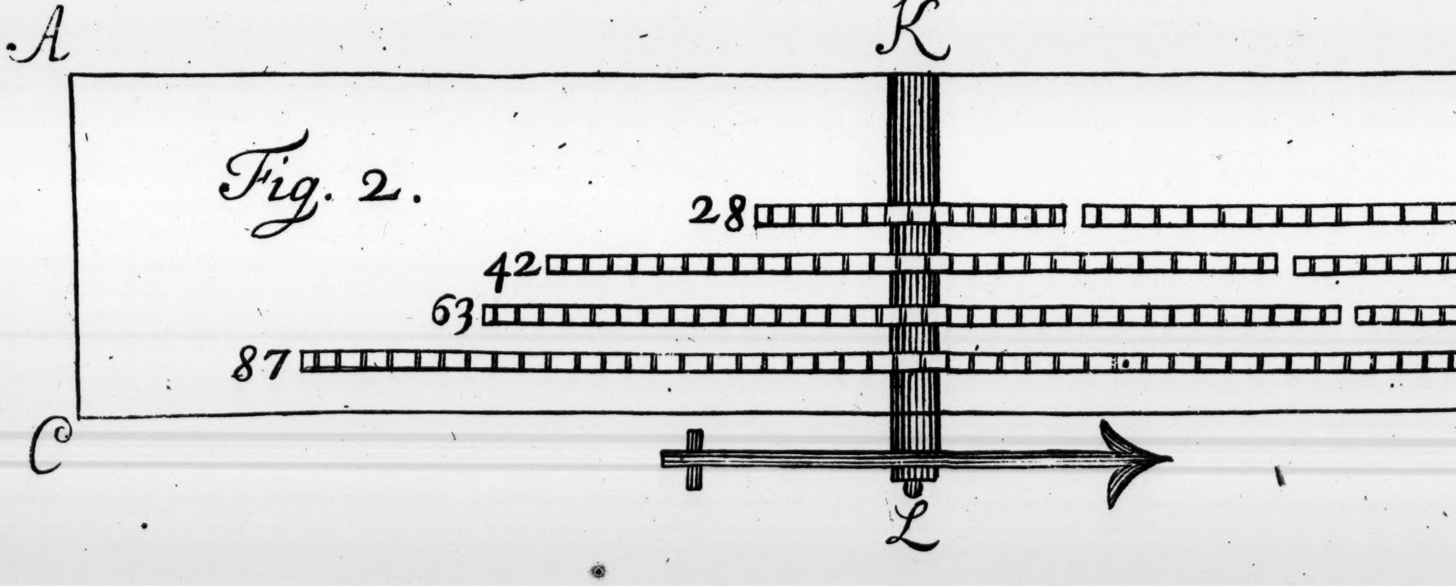
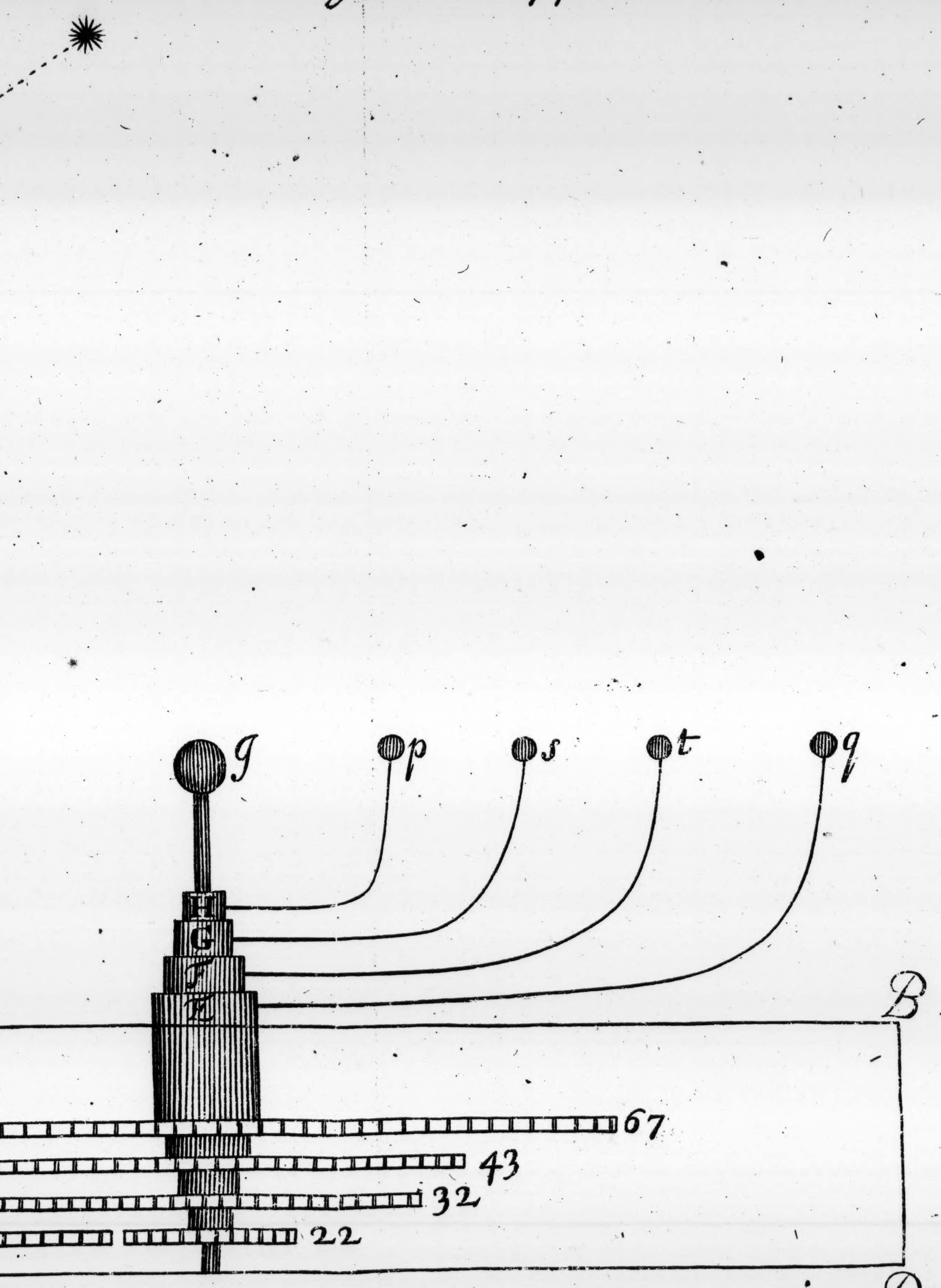



Fig. 2.



Page 22.d Appendix



bear the Plumb-lines (E. F.) and to turn backward and forward, so as to bring the Plumb-lines to the Sights at any time. Place this instrument on a Pedestal (G. H.) to turn round on it stiffly.

Your instrument being thus prepar'd, plant it in some convenient place, where you may see the Pole star, by night, and the Sun by day. When the Pole-star is on the Meridian, look thro the Sight with the bigger Hole, and turn the whole instrument about until you see the opposite Plumb line intersect the Pole-star. Take care at the same time, that the Plumb-lines hang so as to intersect the Sights. Your instrument, thus plac'd, standeth nicely in the Meridian, so as to see when either Sun, Moon, or Stars come on the Meridian.

When you look by night, 'tis necessary that a Candle should shine on the Plumb-line, that you may see it.

If you look at the Sun, you must guard your eye against the Sun-beams with a coloured Glass, or one blackened with the smoak of a Candle.

I had almost forgotten, to say that it matters not much what length the bottom piece, A. B. is of (but the longer the better) provided that the Plumb-lines are high enough to see the Pole-

ſtar, and the Sun in the Summer Solſtice, or any time of the Year. If the bottom piece be 2 feet long, the Plumb-lines had need to be near 4 feet.

This inſtrument is very ſerviceable to ſeveral purpoſes: particularly 1. To ſee the *Southing* of the Sun, or Moon: which you may do with great exactneſs. You may ſee nicely when the very edge of the Sun or Moon toucheth the Meridian, and whilſt all their body is paſſing it.

2. You may ſee what Stars are, at any time, on the Meridian, either Northward or Southward, and ſo find the hour of the night.

3. You may with all exactneſs continue your Meridian-line for many Miles, if you pleaſe, by looking thro either Sight, and ſeeing what objects the Plumb lines interſect.

4. If you would be ſtill more nice, you may apply a *Teleſcope* to this *Meridian Inſtrument*, by placing, for the Eye-glaſs, a Convex glaſs, of a convenient *Focus*, at a due diſtance between the Plumb-line and either Sight, ſo as thro the Sight to ſee the Plumb-line thro the Convex glaſs (or Eye-glaſs.) And at a convenient diſtance from the Inſtrument, place another Convex-glaſs for the Object-glaſs.

5. If I am not much miſtaken this *Meridian-Inſtrument* may as well (and being made Teleſcopulous) much better ſerve the deſign of trying whether the Meridian differeth or not; which ſome have experimented with more trouble and expence than this inſtrument comes to.

6. This Inſtrument is very eaſily brought to the Meridian. For whether it ſtands upright, aſide, or any other way, ſtill the Plumb-lines may be brought eaſily to their due place.

7. This inſtrument is prepared with little coſt or trouble; it may be carried from place to place; or imitated wherever there is occaſion to correct either Sun Dial or Watch.

## A Table, shewing the Time when the Pole-Star is on the Meridian.

| M. | January. | | February. | | March. | | April. | | August. | | Septemb. | | October. | | Novemb. | | Decemb. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D. | Hour. | Min. | Hour. | Min. | Hour. | Min. | Hour. | Min. | Hour. | Min. | Hour. | Min. | Hour. | Min. | Hour. | Min. | Hour. | Min. |
| | Morning. | | Morning. | | Morn. | | Evening. | | Morning. | | Morn. | | Evening. | | Evening. | | Evening. | |
| 5 | 4 | 45 | 2 | 40 | 0 | 51 | 10 | 55 | 2 | 54 | 1 | 1 | 11 | 8 | 9 | 6 | 6 | 57 |
| 10 | 4 | 23 | 2 | 21 | 0 | 33 | 10 | 37 | 2 | 34 | 0 | 42 | 10 | 49 | 8 | 46 | 6 | 35 |
| 15 | 4 | 3 | 2 | 2 | 0 | 15 | 10 | 18 | 2 | 17 | 0 | 24 | 10 | 30 | 8 | 25 | 6 | 12 |
| | | | | | Even. | | | | | | | | | | | | | |
| 20 | 3 | 42 | 1 | 43 | 11 | 54 | 9 | 59 | 1 | 58 | 0 | 6 | 10 | 11 | 8 | 3 | 5 | 51 |
| | | | | | | | | | | | Even. | | | | | | | |
| 25 | 3 | 22 | 1 | 24 | 11 | 35 | 9 | 40 | 1 | 40 | 11 | 47 | 9 | 50 | 7 | 41 | 5 | 29 |
| 30 | 3 | 00 | | | 11 | 17 | 9 | 21 | 1 | 22 | 11 | 29 | 9 | 30 | 7 | 20 | 5 | [illegible] |

This Table is intended for the unskilful Reader, to whom it may be of uſe for ſome years. But it will in time run out, by reaſon of the increaſe of the Pole-ſtar's R. Aſcention, Leap year, *&c.*

The Hour and Minute when the Pole-ſtar comes on the Meridian is ſhewn every fifth day. But in *May*, *June*, and *July* it cannot be ſeen, when it is on the Meridian, by reaſon of Daylight.

The Table will be ſufficiently explained by an Example or two. *Jan.* 5. The Pole-ſtar comes to the Meridian at 45 minutes after 4 of clock in the morning; at which time you may ſet your *Meridian-Inſtrument.* So you may do the ſame, on *Mar.* 20th at 54, after 11 of clock at night, at which time alſo the Pole-ſtar is on the Meridian.

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## VI.

### *To make a Teleſcope for the Government of Watches.*

In *chap.* 11. I mentioned a *Teleſcope* for the governing a Watch by the *Fixed Stars.* And becauſe it is the niceſt way I have mentioned (by reaſon you may ſee a Star paſs at one Beat of a Pendulum) therefore I ſhall here deſcribe the way to make ſuch a *Teleſcope*, as is needful for this purpoſe.

Pre-

Prepare your ſelf with two Convex glaſſes: the one (for the Object-glaſs) to have its *Focus*, or *Cons* about 6 feet, or according to the length you intend your Teleſcope: the other glaſs (for the eye-glaſs) about 2 or 3 inches. Lodge theſe Glaſſes in a Tube of thin boards, paſt-board, or what you think fit. Between the *Object* and *Eye-glaſs*, at the focal diſtance of the *Eye-glaſs* (*viz* about 3 inches) place two fine Hairs or Threads acroſs, ſo as to be ſeen clearly when you look thro the *Eye-glaſs*. Let there be an aperture near theſe croſs hairs, that the light of a Candle may ſhine on them, in the night, when you look at a Star. It is convenient that the *Eye-glaſs* and Croſs-Hairs or Threads, ſhould be lodged in a ſhort leſſer Tube by themſelves, ſo as to go into, and ſlide backward and forward, in the end of the larger Tube; whereby you may ſet the *Eye-glaſs* and *Croſs-Strings* nearer unto, or farther off from the *Object-Glaſs*. Alſo there muſt be a conical Socket of Wood before the *Eye-glaſs*, ſuch as is uſual in all Teleſcopes, to look thro: but its perforation muſt be very ſmall, ſo as only to give you leave to ſee the Star through it.

Your *Teleſcope* being thus prepared, you muſt plant it for obſervation, as is directed in the foregoing Book.

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